

The Blast Furnace Steel Plant

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The Blast Furnace *and* Steel Plant

Vol. XVI

PITTSBURGH, PA., JUNE, 1928

No. 6

Steam Engineers in Lead

IN the endeavor to reach the highest attainable degree of perfection in the operation of equipment power plant engineers have established an enviable record. A decade ago a boiler efficiency of 70 per cent to 75 per cent was considered acceptable practice, but today a plant equipped with boilers of present-day design, the most modern means of burning fuel, air preheaters, water cooled furnace walls, etc., may attain a monthly efficiency of 87 per cent to 90 per cent. Thus the increase in efficiency in the generation of steam has been much greater than in any other operation involving heat.

If an investigation is made to determine the means whereby this increase was effected it will be found that it was brought about by the adaptation of devices involving principles in no way novel. For instance, water cooled walls are to be found in marine type boilers, powdered coal, now so popular, was burned in boilers decades ago; air has been preheated since the days of Nielsen, etc. But it did require ingenuity of a high order to make the adaptation as every piece of equipment, to serve its purpose in a new environment, had to be redesigned—only the principle survived.

What has been done in promoting the increase of service in the generation of steam can probably be duplicated, although to a lesser degree, in other heating processes. It may be possible to refashion, according to modern engineering methods and with modern materials, equipment which in by-gone days did not measure up to requirements. Here is surely an enticing field for the research engineer.

American Iron and Steel Institute Meets

Attendance Exceptionally Large—Mr. Schwab Declares "Distribution" a Weakness of the Industry—Papers Cover a Diversity of Subjects—British Institute Will Meet in United States

THE thirty-third general meeting of the Iron and Steel Institute was held in New York, May 25th, at the Hotel Commodore. That these meetings are maintaining their popularity and attractiveness was made apparent not only by the large registration, which this year was 1,634, but also by the interest manifested by those attending the sessions.

The forenoon session was opened by the address of the president, Mr. Charles M. Schwab, who drew attention to the "small return which the steel industry is currently receiving." This was the theme of Mr. Schwab's address and on this phase of the commercial aspect of the industry he asked the consideration of the members of the institute. As to the remedies two were proposed. "The two most obvious remedies are, of course, reductions in cost or an increase in prices. to the first suggestion I would say that the steel industry has already gone very far in reductions in cost, the experience of my own company showing a total reduction of \$7.27 per ton in the average cost of production between 1923 and 1927. While there are still opportunities for further reductions of cost, we know that we cannot take off much more from cost of production, certainly not without the expenditure of large amounts of capital, and that money can be provided only from earnings or from borrowings which are made from the public and which can, in turn, be justified only by earnings.

"An increase of prices in the industry would be helpful to the industry and fair from the point of view of its customers. But there is another possibility of increasing earnings without either reducing costs further and without increasing prices further which I want to suggest to you for your consideration, and that is the elimination of waste in our industry due to its methods of distribution. One of the principal instances of such waste is the cross hauling of steel products.

"It is manifestly uneconomic for a steel manufacturer in Chicago to ship 100,000 tons of steel to Pittsburgh at a time when a Pittsburgh manufacturer is shipping a like quantity of like material from Pittsburgh to Chicago. The sales in each case must be made at prices prevailing in the districts where the steel is sold and consequently the sales price nets less to the manufacturer in each case than they would have netted if the Chicago manufacturer had supplied the Chicago market and the Pittsburgh manufacturer the Pittsburgh market.

"It should be obvious that this waste is paid for jointly, although perhaps indirectly, by the consumer as well as the producer of steel products. The hunger for tonnage and desire to operate at capacity which is now and has always been one of the fundamental mistakes of our industry, has probably been the chief cause of cross hauling.

"Many of us have for a long time been thinking along these lines, and yet have felt powerless to remedy the situation. Surely where laws force uneconomic conditions into existence one may well consider whether the laws should not be changed."

Professor of Metallurgy, Massachusetts Institute of Technology, Dr. G. B. Waterhouse followed Mr. Schwab by presenting a paper on "Basic Open-Hearth Practice."

The Effect of Coal Segregation, Mixing and Heating Upon the Quality of Metallurgical Coke was the subject of a paper by F. F. Marquard, assistant general superintendent, Carnegie Steel Company, Clairton, Pa. Mr. Marquard's papers gives much detailed information on the preparation of coal for coking and the results obtained when the coke is burned in blast furnaces.

Mr. E. C. Smith of the Central Alloy Steel Corporation described in his paper The Manufacture of Alloy Steels. In this paper Mr. Smith has incorporated information obtained from years of research by the company of which he is assistant general superintendent.

The closing paper at the forenoon session was presented by Mr. Howard Corning of Harvard University. It was entitled the First Iron Works in America—1645.

At the afternoon session three papers were read. Waste Heat Boilers by R. H. Stevens, chief engineer of the Cambria plant of the Bethlehem Steel Company, was the opening paper and was followed by the Trend in Ingot Mold Design by R. H. Watson, assistant general superintendent of the Homestead works of the Carnegie Steel Company. The concluding paper, a Modern Steel Works Power and Blower Plant was presented by Mr. Wilfred Sykes, assistant general superintendent of the Inland Steel Company.

Announcement by Mr. Schwab, that the directors of the institute recommended a bronze medal, in commemoration of Judge Elbert H. Gary, be awarded to the person presenting the best paper at the yearly meeting, was received with favor and given a unanimous vote of approval. A committee will be appointed to carry out this recommendation. Mr. Schwab also announced that the British Iron & Steel Institute had accepted the invitation of the American Institute to hold its meeting in 1932 in the United States. Favorable action was taken on the recommendation of the directors that the number of directors be increased from 24 to 30. The six directors will be elected at a future meeting.

Brief remarks were made by several directors and by Sir William Ellis, chairman of John Brown & Company, Sheffield, Eng., Colonel Thomas Cantley, former president of the Nova Scotia Steel & Coal Company, and G. M. Verity, president of the American Rolling Mill Company.

As is usual at all meetings of the institute, the banquet proved to be exceedingly popular. The speakers were Mr. Schwab, Sir William Ellis and General Herbert M. Lord, United States director of the bureau of budge.

The papers by Mr. Waterhouse, Mr. Marquard, Mr. Smith and Mr. Watson appear in full, or in part, on the following pages of this issue. The remaining papers will be found in future issues.

The Effect of Coal Segregation, Mixing and Heating Upon the Quality of Metallurgical Coke*

Properties of Coals Found in the United States—Selection of Coals for Coking—Mixing Coals—Coking Temperatures and the Results in the Blast Furnace

By F. F. MARQUARD†

WE, who benefit so much from coal, are among the first of the many billions that have lived to realize its potentialities, and we have built a social and industrial edifice upon power. No other natural and economic source of power has been discovered or visualized, unless it be the harnessing of the atom, that can do more than a fraction of what coal does. The world has used coal only a short time. Within the last century its use has developed into one of the most important among commercial factors. No country has reached an eminent industrial position which has not had large supplies of coal within its borders or had ready access to them, for scarcely any home among white races can exist without its use, directly or indirectly.

To the masses, coal may be only a black substance capable of dissipating heat, but to us it is a source of knowledge and power; it is a key to mysteries surrounding our geologic past. Coal has certain marked, definite stages of development. First it is vegetation, next it is peat, then it becomes brown coal or lignite, then bituminous and then anthracite. One distinctive feature in the development or classification of coal is the range in volatile constituents from 45 per cent in lignite to less than 3 per cent in anthracite.

Lignite	45% and over	Volatile Matter	
Sub-bituminous	45 to 40%	"	"
Bituminous	40 to 25%	"	"
Semi-bituminous	25 to 15%	"	"
Semi-anthracite	15 to 8%	"	"
Anthracite	8% and less	"	"

Coals of sub-bituminous, bituminous and semi-bituminous classifications comprise the major portion of all the coals used for coking purposes in the United States and as a class generally can be termed coking or caking coals. Many seams of coal of various chemical and physical properties are included in this class, some of which upon carbonization form an excellent coke, while others possess this quality to a much less degree. These variable qualities are due to many factors, the very nature of the original vegetation from which these coals developed, the geologic age in which they were laid down, the intensity of heat and pressure, and the extent of oxidation and deterioration.

Investigators have attempted to classify coals according to their coking properties deducted from the chemical analysis, such as the ratio of carbon to hydrogen, or of volatile constituents to fixed carbon. These empirical

*Paper delivered before the American Iron and Steel Institute, New York, May 25, 1928.

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schemes have failed in many cases, for certain coals with similar chemical analysis possess widely different coking properties. The present age has found no yardstick to measure this elusive but essential property.

Some coals possess this property to a greater degree than others but under proper segregation, sizing, mixing and heat treatment many coals, that in former years were classified as non-coking coals, are being successfully carbonized into a good quality metallurgical coke.

Coking coals are widely distributed over the United States. They vary greatly in their chemical and physical structure and react differently when subjected to the heating of coking operations. Coals with a volatile content of as low as 16 per cent, such as Pocahontas or Somerset, and a volatile content as high as 40 per cent, such as Colorado or Mexican, and all stages between these limits are now successfully used for coking purposes.

The low-volatile coals are not successfully carbonized by themselves on account of insufficient contraction during the coking period, thus making it difficult or impossible to push the coke from the oven. The high-volatile coals as a rule possess too great a contractive property which is conducive to the formation of fingery masses of coke which have many cross fractures and are readily broken into sizes too small for efficient use in the blast furnace.

Mixing of Coals

On account of this variation in the contracting nature of different coals, it has been found that a mixture of high-volatile coal with as little as 15 per cent of low-volatile coal greatly minimizes the contraction and produces a hard metallurgical coke much desired for blast furnace consumption. It should be pointed out, however, that the mixing of low-volatile coal with high-volatile coal involves the economic problem of increased cost versus decreased consumption of coke at the furnace. Each by-product coke oven plant is an individual problem, and cases will be found where the decreased consumption at the furnace would be more than offset by the increased cost of a low-volatile coal mixture.

The volatile constituents are not the only determining factors that affect the coking properties of coal. Resinous and cellulose compounds react during the coking process, the result of which greatly affects the quality of the resultant coke. Oxidation may entirely eliminate the coking quality of coal. In the Pittsburgh seam, within narrow confines, coals may be found below a very shallow over-burden that have oxidized to such an extent that they will not coke, yet within a comparatively short distance under greater cover excellent coking coals will be found. Slaty material likewise has a detrimental effect upon the

quality of the coke produced, especially if the coal is not prepared by pulverization. Hair cracks and cross fractures emanate from slate in the coke which result in an excessive amount of small coke and dust. However, due to the coarse nature of the slate, a major portion of it is screened from the furnace coke in the fines. If the slaty material is pulverized in the preparation of the coal, it is absorbed in the coke mass and while it loses much of its detrimental effect upon the physical qualities of the coke, yet the furnace coke will be proportionally higher in ash and the advantages gained by this pulverization in physical properties of the coke are largely counteracted by more difficult operations and the increased cost of production in addition to the increase in ash in the resultant coke. The solution is then neither the pulverization of the slate with the coal, nor the screening of the slate and small coke from the furnace coke, but in putting forth every effort to have the slate reduced to a minimum in the mining or cleaning operation.

Before any specific treatment of coal is outlined it is quite important that a complete survey of the coal to be carbonized is available. That which may improve the coking qualities of one coal may be inadequate for another coal having approximately the same chemical analysis. It is important in the design of the ovens that consideration be given to the quality of coal to be charged. The width of the oven, the taper and the distance of the horizontal flue below the coal line are important factors in the production of a better quality of metallurgical coke from certain types of coal.

The ash and sulphur determinations of coal are very important for the chemical quality of coke, but they are not determining factors in the coking characteristics of coals used for the production of metallurgical coke. Owing to the lack of proper laboratory testing methods for determining the coking properties of coal, the quality of the resultant coke is determined mainly by actual furnace operations using the coke.

Value of Coke

It can readily be seen that this basis of determining the value of the coke will give as many different results as there are different furnaces and different furnace operations. The value of the coke from these operations will vary with the construction of the furnace and the wisdom and resourcefulness of the blast furnace operator.

It has happened, not once, but many times, in my experience that a certain coke shipped to different furnaces simultaneously has been criticized severely by one furnace operator, while at the same time it has been praised for its exceptional quality by another furnace operator; the first operator getting poor furnace results and the other operator getting good furnace results. I might add that both operators may be perfectly honest in their opinion, but their opinions were formulated from their furnace operation.

It is perfectly apparent that there are many other influences affecting the furnace operations that are responsible for furnace performance beside the coke variations, therefore, instead of spending an unreasonable sum of money in an effort to effect some small improvement in the coke quality, it may be much more economical to make changes in the furnace lines and especially in the conditioning of the iron ore by sintering the fines.

I heard one blast furnace man say recently that he averaged 935 gross tons of pig iron per day from one of his furnaces over a period of three months when using

a coke made from 15 per cent Somerset and 85 per cent of high-volatile Pittsburgh coal, half of which was washed, and when he ran this furnace for a month on coke made from 100 per cent high-volatile coal without mixing in the low-volatile coal, the monthly average was 835 tons. Even with 11 per cent increase in tonnage it would be difficult to justify using 15 per cent low-volatile coal in the mixing in the Pittsburgh district, where the low-volatile coal costs 50 per cent more delivered than the high-volatile coal. In addition to this difference in the price of the two coals, the net value of the by-products from a ton of high-volatile coal is very materially higher than the value of the by-products of the low-volatile coal; so that an addition of 15 per cent of Somerset low-volatile coal to the high-volatile coal would result in about a 20 per cent increase in the cost of by-product coke in the Pittsburgh district.

Thus in the face of these figures and the extra cost of equipment and preparation of coal for mixing, we were compelled to direct all of our efforts towards improving our coke as much as possible with the use of 100 per cent high-volatile coal in order to save the extra cost of importing distant low-volatile coals and the loss of the by-product returns, for we cannot afford to lose the great advantages the Pittsburgh district should enjoy from cheap coke. Only in extreme cases, where some of our high-volatile coals would not make good coke on account of extreme brittleness accompanied with high sulphur and ash content, have we considered that it may be profitable to use 15 per cent low-volatile coal.

With these facts in mind our entire forces were directed in an intensified study of our Klondike coals to make the best metallurgical coke possible from the use of 100 per cent high-volatile coal.

By product carbonization of coal for metallurgical coke dates back approximately 30 years in this country. This whole development has taken place almost entirely within the time of my connection with this industry.

Preparation of Coal For Coking

Segregation of coals, cleaning of coals, mixing of different kinds of coal, and crushing to the various degrees of fineness are resorted to to improve the coke quality for blast furnace operation. In the early history of by-product coking at the Farrell by-product plant, which was completed in 1903, we went through a long series of experiments to determine the proper preparation of the coal to produce the best quality of coke; its degree of fineness, and how much low-volatile coal (Pocahontas) had to be added to get a suitable blast furnace coke.

We had theories, but no experience upon which to base our conclusions; our standard of testing coke did not give us conclusive information and we were very largely guided by the reports of the blast furnace operators, who at best were more or less prejudiced against by-product coke, because of its general dull appearance and small size. As one of the blast furnace men has told me, he did not care how much his production has improved on by-product coke or what the results of his furnace practice was, by-product coke was "no damn good." Strange as it may seem now, this was the general impression of the blast furnace man, and it took years to overcome this prejudice.

While there was considerable improvement made in the quality of the by-product coke, this improvement

was not made in any great leaps and bounds, it was gradual and all the time students in the coking industry were getting into the subject deeper, trying to get at the real reason or combination of reasons why one coal, having approximately the same chemical analysis as another, should show decidedly different coking characteristics.

One big question affecting coke quality seems to have been pretty generally settled, that is, by mixing a certain percentage of Pocahontas coal (low-volatile) with a higher volatile coking coal a noticeable improvement in coke structure is secured. But this is only evading the question. Why is this true? And can we not produce a quality of coke equally as good, without sacrificing the by-products, as we do in using Pocahontas coal in by-product ovens?

On the basis of tests made on the coking of 100 per cent high-volatile (Klondike) coals at Farrell in 1906 to 1913, it was decided that a fairly good coke could be made without the mixing of Pocahontas coal, even in the poorly designed ovens at Farrell. These results speeded up the plans for the construction of the large modern plant at Clairton, designed to use 100 per cent high-volatile coal. This plant was projected in 1915, and put into operation in 1918. At that time we did not think we were going to be able to make a coke as good as the coke made from the Pocahontas coal mixture, but we expect to make a fairly good coke and much cheaper than the coke made from Pocahontas mixture, so that the furnace could afford to suffer somewhat in higher coke consumption and lower iron production and on the whole make pig iron very much cheaper than by the use of a coke made with a Pocahontas mixture.

Thus we worked on through one campaign of blast furnace theories after another until the furnace men began to demand a harder coke at almost any cost within reason in order to meet the requirements for their larger hearth, large production, higher heat, furnace operations.

Coking Temperatures

In the spring of 1925, we started an investigation to explore the whole range of coke temperatures from 1,600 to 2,100 deg. F., and from short coking time. It was after these tests, which embodied the test results of 23 blast furnaces over a period of months, that we concluded that the high temperature coke around 2,100 deg. F. greatly improved the structure of our coke made from 100 per cent Klondike coal. Since that time we have consistently operated the Clairton ovens to produce a coke of 2,100 deg. F. as compared with previous operations of 1,850 deg. F.

However, while on the average our results were greatly improved and our large blast furnace productions of iron equaled and in some cases even exceeded furnace of equal dimensions using Pocahontas mixture, we continued to have short spells of off-grade coke which led us to believe that our different high-volatile coals had different coking properties, notwithstanding the fact that they all came from an area of 25 miles, all of the Klondike region Pittsburgh seam, and each had approximately the same percentage of volatile matter.

Thus our next step in the improvement of our coke was effected by the isolation of these different Klondike coals, coking each of the several coals separately. We now have five separate groups of coals, known respectively as Gates, Colonial, Palmer, Ronco and

Bridgeport. After separating our coals in these groups, we began to find out that each coal had definite coking characteristics and once we regulated our coking temperatures, constant coking conditions could be maintained. A further advantage was that the ash and sulphur contents of the various groups were comparatively constant and gave the furnace operator better knowledge of the coke chemistry for his furnace.

The cokes made from the different coals are all marked separately and shipped to definite furnaces, thus eliminating as many variables as possible, because the furnace men say there is nothing quite as conducive to good furnace operations as uniformity of material and conditions.

We have now reached the stage where the big factors in the coking of coals from a certain district are pretty well solved. However, certain groups, like Palmer coal, were made up of a combination of four to five workings, so that another phase of investigation was opened up and we are now passing through a stage of refinement, so to speak, in the coking operation.

When I say refinement I do not wish to minimize the importance of these refinements, but only wish to point out that it was useless to spend time and energy on refinement of an operation before the major problems in our operation have been definitely settled. For example, we have demonstrated that certain of our large furnaces could produce consistently an average of over 800 tons of pig iron per day on Clairton by-product coke, made from 100 per cent high-volatile coals. Why then do not all the large furnaces consistently make these large tonnages on other Clairton coke made from 100 per cent high-volatile coals? That is a big question and the answer does not lie entirely in the quality of the coke used.

Pyridine Solubility

Our first study of the various coals used led us to the investigation of pyridine solubility; we found that coals of about the same volatile matter differed widely in pyridine solubility. Some coals showed over 28 per cent soluble resins in pyridine extracts, while others showed as low as 15 per cent, with coals of the same percentage of volatile matter (about 33 per cent). So we began investigation on the coking properties of coals with low pyridine solubility as compared to coals of high pyridine solubility.

We found in some cases that the pyridine solubility bore a relationship to the oxygen content of the coal, but our continued studies did not reveal the coking secret, for coals with low pyridine solubility showed coking properties equally as good as did coal with high pyridine solubility, except in cases where low pyridine solubility was combined with high oxygen content, which destroyed the coking properties. We also found that two coals with different pyridine solubility in some instances made good coke when coked separately or combined. We found that by extracting the resins with pyridine, we could destroy the coking properties of a coal, and also restore the coking qualities by the addition of the resins extracted from other coals.

From these results we concluded that evidently the resinic compounds contained certain properties necessary for a coke-forming coal, but the mere knowledge that our coals contained certain percentages of these compounds did not give us the required information. Since the resinic compounds as a whole are made up of the coke-forming constituents of a coal, it was thought possible that a further separation of the resinic com-

pound, by the extraction with various solvents, might isolate some definite constituent which would give us an index of the coking properties. Thus in our study of separation and extension of the resinic compounds by the action of all the known solvents, under varied conditions of temperature and pressure, we were led to believe that the reaction of these bodies during the intumescent stage of the coking process was more indicative of the quality of coke formation than the extraction or separation of these resinic bodies. This led to an investigation of the melting or plastic temperatures of the coal.

Thus it was found by making melting tests on our coals that coals of the same general analysis showed different temperatures accompanied by relatively different emission of gases when they were heated up to the plastic state. The gasifying rates and plastic temperatures of several of the coals investigated are shown by the following curves (Fig. 1).

The melting points are indicated by the initial sharp increase in pressure shown by each curve, and an indi-

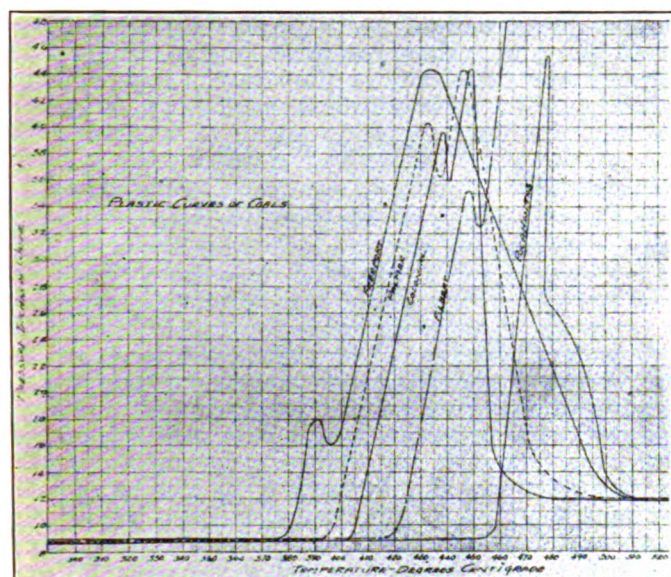


FIG. 1—Gasifying rates and plastic temperatures of coals investigated.

cation of the gases evolved is shown by the area under the curve.

Thus for example the Freeport coal shows a greater emission of gases during the plastic stage than any of the coals studied. Likewise, Filbert coal shows a rapid evolution of gas during the stage of heating.

The following table shows the comparative volatile constituents of the coals before and after heating to the

	Vol. mat.		Melting temp. °C.	Highest temp. heated °C.	Coking properties of the residue
	Before Per Cent.	After Per cent.			
Palmer	32.00	15.00	394	500	Good
Filbert	32.50	12.50	420	500	Good
Colonial	32.20	19.00	402	500	Good
Freeport	32.75	10.10	378	500	Nil
Pocahontas ..	16.58	8.20	455	500	Nil

plastic state, and the residual coking power of the coals after once becoming plastic.

From a study of the foregoing data it was evident that the Filbert coal had different melting characteristics than the Palmer coal. This discovery led us to isolate the Filbert coal from the Ralph, Lambert and Palmer, a mixture which was coming out of the same mine opening and all being shipped in under the name of Palmer coal. The Filbert coal began to gasify at 420 deg. C., while the other coals of this group would begin to throw off gases at 390 deg. C. It became evident then that if we mixed Filbert coal of one melting characteristic with coal of a different melting characteristic, the result would be that the emission of the gases from the Filbert coals would greatly disturb the cell structure of the other coals in their intumescent stages and give us a poor coke structure. This is apparently what has happened, and by isolating the Filbert coal from the other coals, the coke quality was materially improved in strength and hardness. We also found that if we would coke the Filbert coal by itself, or in combination with other coal having the same melting or gassing properties, we could produce a very good coke, but in combination with other coals of different melting characteristics, the coke was of poorer quality.

It is interesting to note that the Freeport coal shown in the foregoing data shows almost identical chemical properties, by the usual chemical analysis, as the Palmer, Colonial, and other coals used at the Clairton plant. Yet, by a study of the melting characteristics, it is evident that it has entirely different properties and formed an inferior coke.

We have been able in many instances through the study of melting curves to predetermine the coking characteristics of the individual coals, and by varying our oven temperatures and segregating our coals we were able to bring about a considerable improvement of the coke structure.

A further study has revealed the fact that the melting point of the coal is affected by the presence of slate. By the removal of free slate we can lower the melting point of our coals. On a large scale operation we have shown that by the removal of slate from Palmer coal the melting point of this coal was lowered approximately 50 deg. C. This lowering of the melting point enabled us to materially improve the coke structure by a change in the heating.

(To be Continued.)

Engineering Foundation Seeks to Increase Endowment

The endowment committee for Engineering Foundation and Engineering Societies Library, to which the Hon. Herbert Hoover was recently appointed by the United Engineering Society, has announced its intention of securing a fund of \$5,000,000 to expand its program better to meet the needs of industry.

Engineering Foundation, an organization to aid advances in the use of the sciences, was organized about 13 years ago on the basis of a generous gift from Ambrose Swasey of Cleveland, Ohio. This has been supplemented by large gifts from Henry R. Towne, Edward Dean Adams and others. The income has been used to promote research, largely under the direction of the four great engineering societies.

The Trend of Ingot Mold Design*

The Present Tendencies in the Design of Ingot Molds Is Discussed Based on Carefully Observed Practice—Life of Molds Secondary to Steel Quality

By RALPH H. WATSON†

MOLTEN steel poured into an iron mold freezes in three distinct phases. The first is a very thin skin of fine-grained crystals. This is followed immediately by the well-known columnar crystals approximately perpendicular to the mold wall, which grow inward as long as influenced by the chill of the mold. They end rather abruptly, and the third phase, the formation of equiaxial crystals, completes the solidification. This crystallization, as well as the other two phases, takes place, as would be expected, roughly parallel to the walls of the mold and stool. Crystal growth, both in the case of the columnar and the equiaxial crystals, is by the process of selective crystallization. The purer crystals separate out first, causing the mother liquor to be progressively enriched until the last to freeze carries a considerable enrichment of carbon, phosphorus, manganese, sulphur, and other constituents of steel. This is segregation. Molten steel takes up more room than the metal solidified. The outer wall of the ingot is formed approximately at its final size while the interior of the ingot is still molten. The freezing is progressive from the outside. The final deficit in volume occurs along the central axis. This is pipe.

The influence of taper on the freezing of the ingot is the starting point of any discussion of mold effect. A

effect of taper in both the big-end-up and the big-end-down hold. It is obvious that the converging lines of freezing metal will in the first shut the gate to the flow of metal from above, while in the second the larger mass of metal, and therefore the last to cool, is at the top where it can feed the shrinking mass below, and prevent pipe formation. There are modifying influences, otherwise the pipe in the ordinary ingot would be deeper than is actually the case. It is suggested by Brearley that the equiaxial crystals settle to the bottom as well as cling to the sides of the solidifying ingot. Professor Howe² describes the sagging of the later frozen metal as another influence to lessen the pipe. However great, the modifying influences tending to limit it, the effect of taper on the ordinary mold is to permit the formation of pipe.

The Question of Taper

Taper is given the mold for ease in stripping and to prevent the hanging of the ingot in the mold. An ingot suspended in the mold will often crack from its own weight or from being held by a fin between the mold and stool. Formerly it was thought that a mold 70 in. to 76 in. long required a taper of two or even three inches. Molds with this maximum taper are in present use. Progressive mold manufacturers now are recognizing that good workmanship and rigid foundry equipment will permit them to make a mold with very little taper that will successfully strip and not cause an ingot to hang. A difference of one inch in top and bottom dimensions is considered liberal, and full-length molds are in successful use with taper as low as one-half inch, i. e., a quarter of an inch to the side. Indeed the necessity of any taper whatever is questionable. The shrinkage of the ingot and the expansion of the mold will permit easy tripping without taper unless the cross section is very small or the mold is more irregular than is now permissible. If a defect develops in the mold no amount of taper will avail, for the steel entering the defect must clear the point immediately below it. The increase in cross section at this point, however great the taper, is infinitesimal. I have recently been using experimentally 25 in. x 25 in. x 78 in. molds without taper. The inside walls of the mold varied at points an eighth of an inch from the straight line. Ingots cast in these molds were stripped without the use of the plunger, and showed no signs of hanging. A mold requires at the most only enough taper to provide against irregularities in the surface. The decrease of taper to the minimum is the first step toward sound ingots.

Before the development of the small-taper mold, attempts had been made, from time to time, to keep the top of the ingot molten long enough to feed the pipe, as it formed, by means of the refractory top or a heating device at the top of the ingot. As long as the large-tapered ordinary mold was used, this attempt was only

²Piping and Segregation in Steel Ingots, Henry M. Howe, Trans. Amer. Inst. Mining Eng., Vol. 38, pp. 3-108 (1907).

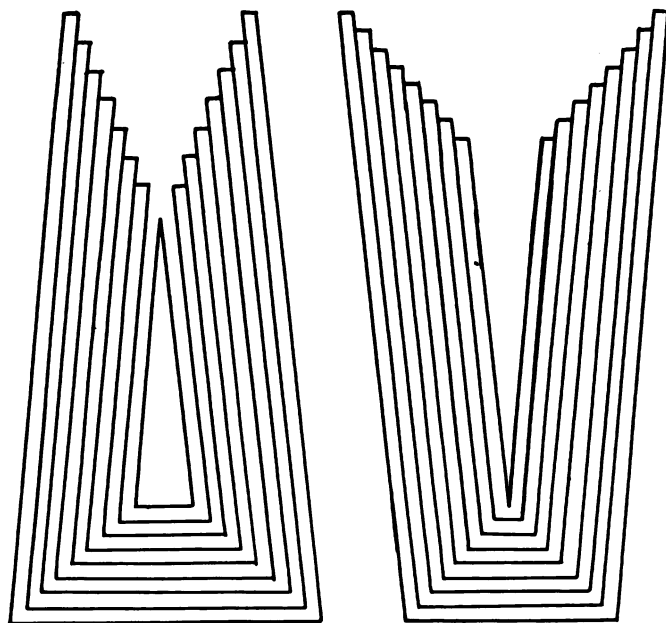


FIG. 1—Theoretical effect of taper in molds with big end down and big end up.

characteristic sketch (Fig. 1), taken from Messrs. Brearley's admirable text book,¹ shows the theoretical

*Abstract of paper presented before the American Iron and Steel Institute at New York, May 25, 1928.

†Assistant general superintendent, Homestead Steel Works, Carnegie Steel Company, Munhall, Pa.

¹Ingots and Ingot Molds, A. W. Brearley and H. Brearley, London, New York.

partially successful, and in few cases except with very large molds was it worth the cost. Manufacturers requiring sound steel, therefore, turned to the big-end-up mold which had been advocated rather warmly for many years. Indeed the literature of molds and ingots pays scant attention to any other type. Without the hot top it is too difficult to strip, and its advantages over the ordinary mold nowhere seemed to justify its adoption. Equipped with the hot top, however, it became the old forge mold, long known to have produced sound ingots for forgings. Open-hearth plants for forge shops usually cast in the pit, strip with the open-hearth crane, and are able to take care of the mold with little difficulty. The tonnage is small. The modern open-hearth plant for the rolling mill casts on buggies, moves the heat promptly to the stripper to make room for other molds at the pouring platform, and in general produces a large fast moving tonnage. The big-end-up mold even with the hot top, which permits easier stripping, does not fit well into these conditions, and its widespread adoption has been delayed on that account. Although the direct cost is considerable, there is always a good chance to recover the additional cost of mold and top by increased product from the ingot. No mold will in itself insure a sound and homogeneous ingot. No such ingot exists. When it is approached it is the product of many factors, only one of which is the mold. Manufacturers of high-grade steel have in general become convinced that even with all other conditions favorable, the old mold is inadequate, that the hot top is necessary, and that the big-end-up hot-top mold gives them a better chance of approaching soundness and uniformity than any mold heretofore used. Nothing is more striking in the present trend of mold practice than the rapidly increasing use of this mold. Much credit for its introduction and its adaptation to steel plant conditions is due to Mr. Emil Gathmann and his associates who have persistently advocated it for many years.

Big-end-up molds for rolling mill ingots have been given considerable taper. This is undesirable from a rolling standpoint, and of doubtful necessity. One reason advanced for larger taper is that the ingot through vertical shrinkage settles down nearer the mold walls, and receives more chilling effect from the mold. When the time required for full vertical shrinkage is considered, and also the fact that the ingot should never make complete contact with the mold and cause a hang, the chilling effect becomes doubtful. Many successful forge molds have small taper. Barba³ recommends the smallest taper that will permit easy stripping. A study of the Report⁴ on the Heterogeneity of Steel Ingots by the subcommittee of the British Iron and Steel Institute shows no advantage in larger taper. Makers of high-grade tool steel, whose ingots vary from 4 in. to 18 in. square, use split molds without taper, or solid molds with little taper. Mr. Gathmann has recently advocated the double-taper mold, tapered heavily at the bottom and less at the top. This is a concession to the rolling mills, but why a large taper at the bottom? Almost any ingot is free from pipe in the lower third, even when the mold is tapered the other way. The lessening of the taper at the top, however, if the large taper is retained, is beneficial. Ingots, especially large ingots, do not

shrink uniformly. We found at Homestead during the war that easing the taper at the top of a heavy Gathmann mold allowed the ingot to clear the mold, and to avoid hanging immediately under the sink-head. The old armor molds at Midvale and Homestead were tapered less at the top than the bottom, to permit the use of an adjustable sink-head to vary the weights of ingot that could be cast in the same mold.

Value of and Requirements for the Hot Top

Although the big-end-down mold with the large taper, even with the hot top, cannot be regarded as successful, this mold with the small taper equipped with a hot top is very promising. The Valley Mold Company has recently developed such a mold with a

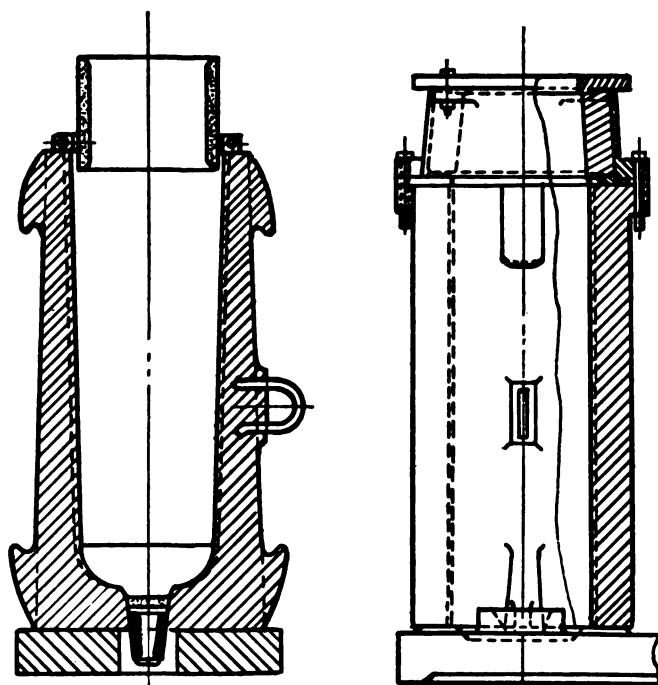


FIG. 2—(left) Gathmann hot-top mold; (right) Valley small-taper mold.

fixed hot top that goes to the stripper like an ordinary mold. The top is a metal casing lined with porous brick having no horizontal joints. A plate, machined on both sides, made of mold iron intervenes between the top and the mold, which is also machined, and the top and plate are clamped rigidly to the mold. With a slurry between heats, the brick top lasts for 30 to 40 heats. This mold has been in use with good results at the Newburg, Worcester, and Donora plants of the American Steel and Wire Company for casting high-carbon steel for fine wire, and is now being tried at several other steel plants. The cost of hot topping is very considerably reduced by the semipermanent top, and the mold with its top is adapted to ordinary open-hearth operations. While this development probably will not supplant the big-end-up hot-top mold, it bids fair to extend considerably the field for hot-top molds. If further use proves it is successful as it now appears, it will be a boon to plants requiring a better mold than that now in use, but which cannot adapt themselves to a large production of big-end-up ingots. One step further is possible, the hot-top mold without taper. These are now being tried at Homestead. Fig. 2 shows, left, the Gathmann big-end hot-top mold, and, right, the Valley small-taper big-end-down hot-top mold.

³W. P. Barba and H. M. Howe, Trans. Amer. Inst. Mining and Metal. Eng., Vol. 67, p. 200 (1922).

⁴Journal, Iron and Steel Institute (London), Vol. 1, 1926, pp. 39-176.

A hot top should have heat insulating qualities sufficient to keep the steel contained molten for the necessary period. It should either release the ingot or itself sink with the contracting ingot to prevent hanging. It should be made of a material that will not flake or spall when subjected to the heat of the stream when top pouring, and thus introduce foreign matter into the ingot. It should leave on the ingot nothing that will subsequently melt in the soaking pits, and run down over the surface of the ingot. It should be easily applied to the mold, and not too costly. None of the tops in present use altogether meets these requirements. The single-piece hot-top brick is the one in greatest favor. Other tops are made of sand, coke, old brick crushed, bricks of various shapes, blast furnace and open-hearth slag poured into forms, and blast furnace slag bonded and formed into shapes.

Effect of Wall Thickness

Opinion on mold wall thickness is at great variance. Ingots of approximately the same size are cast in molds varying from 2½ to 14 in. in thickness at the top. Usually there is a differential between the top and bottom thickness from consideration of economy, mold life, and effect on ingot cooling. Mr. Morris, of the Bethlehem Steel Corporation, who has had a long experience in the design of molds for both forging and rolling ingots, has adopted the rule of making his mold at the top as thin as is compatible with the necessary structural strength for the size in question, and doubling this thickness at the bottom. Such a mold is none too easy to cast with the top up in the mold foundry for the reason that kish separating from the iron during the pour is likely to be entrapped by the sharply converging walls of the foundry mold.

The experiments of Priestley⁵ and Leitner⁶ in cast-

⁵Trans. Amer. Inst. Mining and Metallurgical Eng., Vol. 70 (1924).

⁶Stahl und Eisen, May 13, 1926, pp. 629-631.

ing small ingots in molds of varying wall thickness indicate that there is a limit to the effective thickness of mold wall. Investigators of the Valley Mold Company have approached the problem by measuring the rise in temperature of the mold. I am deeply indebted to Mr. Perry of this company for permission to describe some of their experiments.

A block of mold iron was prepared 12 in. high corresponding to a 20 in. square mold with a wall thickness of each of the four sides of four, six, eight and 10 in. respectively. Starting an inch from the inside wall, midway on the side, holes were drilled every two inches across each wall. The holes were six inches deep with the bottoms made flat. Thermo-couples were inserted pressing closely against the flat bottoms of the holes. The mold was filled with iron at a temperature of 2,350 deg. F. determined by optical pyrometer, and readings taken at intervals of one minute for the first six minutes after pouring, afterwards at longer intervals for half an hour. Fig. 3 is the chart plotted from the temperature readings, and in the upper right-hand corner is a sketch of the equipment used. The chart indicates that the effect on the ingot for the first few minutes, probably during the entire period of the formation of columnar crystals, is practically identical for each thickness of wall. It seems to justify the thin wall at the top of the mold for the effect on pipe, but to my mind shows no quicker cooling with an exceptional thickness at the bottom.

The experiment was repeated using full-sized molds of approximately the same inside dimensions but of varying wall thickness, and casting steel instead of iron. The weights of the molds, all of the same height, were in the approximate ratio of 80, 100 and 180. Top and bottom sections of the molds are shown in Fig. 4. They were drilled for thermo-couples, half way up the length, and readings taken at varying distances from the inside wall both at the middle of the face and at the corners of the mold. (The heavy mold was not read

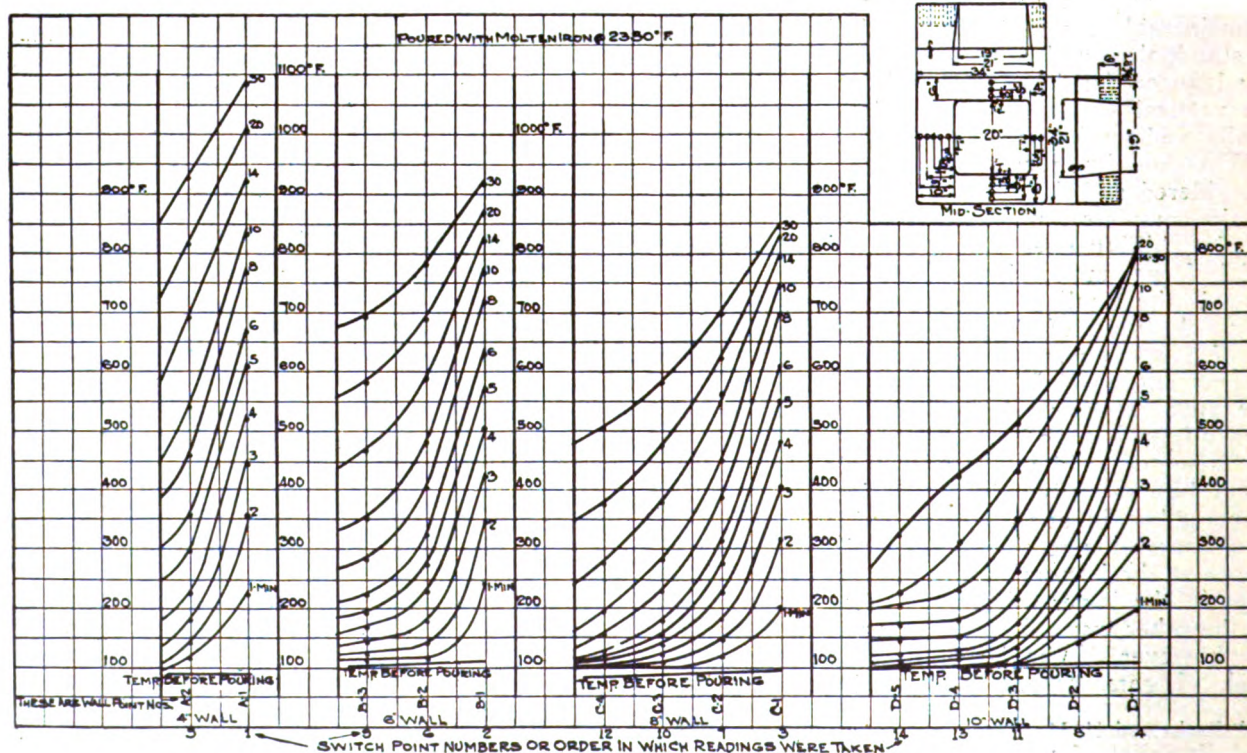


FIG. 3—Chart showing temperature readings made on experimental blocks of mold iron.

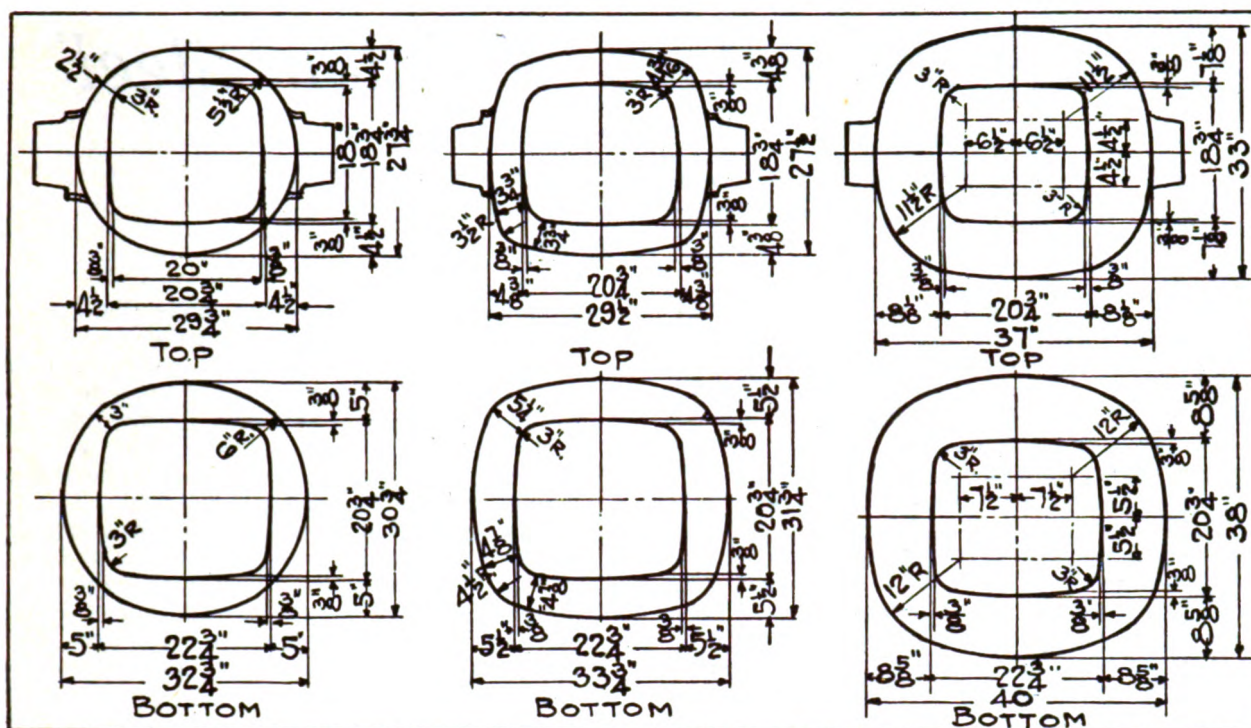


FIG. 4—Top and bottom sections of full sized molds used for experiments.

at the corners.) These readings indicate a somewhat greater effect of wall thickness than did the block test just described. They bring out clearly the lead in cooling given by the comparatively greater mass of mold wall to the corner of the ingot, and the equalizing effect of considerably thinning the wall thickness at the corner. Observations, of which those just described are a type, are of more than academic interest. Based upon them, the research department of the company has worked out what it terms a balanced mold. This is thin at the corners, growing thicker as it approaches the middle of the side. The aim is uniform cooling of the corners with the face of the ingot on the hypothesis than any casting, an ingot included, cooling uniformly will be less subject to strains and crack less than one which cools irregularly. Balanced molds, modified only by the limited strength of iron and a reasonable regard for mold life, are being recommended to their customers.

To determine the effect of wall thickness upon segregation and blow holes, steel from two heats, one of low-carbon rimming steel, and the other of high-carbon silicon-killed steel, were poured in the molds shown in Fig. 4. No pronounced effect of mold wall thickness on segregation is indicated by this experiment, neither was there any pronounced difference, judged from the photographs of the split ingots, in the position of the pipe or in the position of the blow holes in the rimming steel.

I have been able to gather no conclusive data on the effect of mold wall thickness on ingot surface and chipping cost. Opinion there is, probably based upon experience, but opinion at one plant is exactly opposite to that at another. Although it is not safe to generalize from meager information, the Valley experiments indicate that during the skin forming period, mold wall thickness has little influence on rapidity of ingot cooling. Perhaps it is because the influence is negligible that opinion on the subject has not crystallized. The matter is of importance, and accurate information,

when obtained and given out, will be welcomed. Heavy walled molds fire crack more than the lighter, and it is safe to say that thickness added to the mold beyond the point where it no longer fails by through cracks at the top or bottom is uneconomical from the point of view of mold life. The Valley experiments indicate, and it is indeed general knowledge, that there is always an excess of metal at the corners of a rectangular ingot mold. Experience has demonstrated that the mold may be thinned considerably at the corner without detriment to mold life, and with a saving in weight of mold.

(To be Continued.)

Second National Fuels Meeting to be Held in Cleveland

The second national meeting of the Fuel Division of the American Society of Mechanical Engineers will be held in Cleveland, Sept. 17-20, 1928.

A comprehensive program is being planned, which will include papers by a distinguished group of nationally recognized authorities dealing with the production, distribution and efficient utilization of fuel.

The first national fuels meeting held in St. Louis, in October, 1927, was well attended and it was a very valuable meeting to the American Engineer. It is expected that the second meeting to be held in Cleveland next September, will be attended by a much larger delegation, and the active co-operation between the Cleveland local section of the A. S. M. E., and a number of other organizations assures a complete success.

The general arrangements committee under the chairmanship of Colonel Elliott N. Whitlock, consisting of Messrs. A. J. Foley, P. V. Fraser, T. F. Githens, H. K. Kugel, Theodore Maynz, F. H. Vose and John Wolff, promises an exceedingly interesting and noteworthy program.

The Manufacture of Alloy Steel*

Alloy Steel Is Defined and the Processes and Procedure in Its
Manufacture Are Outlined—The Peculiar Spec-
ification Features Are Discussed

By E. C. SMITH†

WITHOUT attempting legal exactitude, an alloy steel may be defined as a steel whose special property or properties are dependant upon the addition of one or more alloying elements. To make this clearer requires definition of the underlying material, steel. Excluding blister steel, which is carburized wrought iron, steel may be defined as an alloy, essentially iron and carbon, cast in an initially malleable mass. Thus we have only three essentials iron, carbon and initial malleability. It may easily be concluded that the definition of an alloy steel rests upon rather uncertain grounds, for all commercial steels have other than the essential iron, carbon and initial malleability. This leads to the conclusion that alloy steels must be special steels and that chemical composition is hardly the vital factor.

Discussion of the entire range of special steels would develop into an elaborate paper in which details would be of questionable value. It is, therefore, proposed in this paper to discuss only the more important phases of those steels whose tonnage has established them as production materials. No attempt will be made to discuss historical development and but little attention can be given to the relation of manufacture to application. These restrictions must be placed and essentially the ground covered will be the field of structural alloy steels, best known as automotive steels.

It has been common to watch the development of any special manufactured product grow from the luxury stage to common widespread application. Where skill and capital have been able to produce a special material at a relatively low cost, it is usual to see widespread application of the product. Thus the luxury of last year is the standard of this. This has been true of the steel industry as of other industries.

The increasing use of alloy steels is certainly demonstrating this. The special, or luxury, form of the industry is rapidly disappearing. The manufacture of special products grows yearly. No single district has a monopoly on special steels; in fact, very few districts exist that do not have steady production of alloy steels.

If it is true that the special product of today will be the standard product of tomorrow, it will be well to consider trends of alloy steel manufacture. Let us consider the present design of plants and their probable adaptability to the developments of the industry as the knowledge of the art of steel making broadens. It may be of more interest to consider the advancing knowledge of steel working. The increased study of routine requirements is establishing the brand type of specification. An alloy steel must meet a very specific set of requirements. If this type of specification is liable to become more widespread, an inquiry into alloy practice conditions will be of interest.

Alloy steels, as defined, did not have any limiting method of production. It is of interest to know that

all the commercial methods of conversion are responsible for some of the tonnage. Thus we find open-hearth furnaces, both basic and acid; electric furnaces, arc and induction; Bessemer converters, both side and bottom blown; and crucibles involved in the total tonnage. Essentially the tonnage comes from two sources—open-hearth and electric furnaces. By far the greatest tonnage is basic open-hearth material. The tonnage of special steels requiring the minor methods of manufacture is gradually narrowing but will hardly disappear. The limitations of basic melting practice overshadow its desirable cost considerations and certain secondary processes will exist until new inventions provide additional flexibility to the dominating process.

Of the secondary processes, the arc type of electric furnace appears most nearly to meet the requirement of a unit that can successfully melt all combinations which are not commercially satisfactory for basic open-hearths. The study should, therefore, cover the essentials of the two dominating processes. The minor production units still furnish considerable material of special combinations in small tonnage, but are more interesting historically than economically. The induction furnace will develop to replace the small production units in specialty melting.

As operated in this country, the essential of the industry is blast furnace pig iron. Without entering into the probable metallurgical reasons for using any other source of primary reduction, it may be stated that the ability of the blast furnace to produce the most economical iron will give it the dominating position until invention provides a cheaper source. This appears reasonable from another viewpoint. Essentially the alloy or special steel business is not a primary conversion. The problem is not to convert the most pig iron into steel, but to use the necessary pig iron to convert steel scrap into special steel products. The production of the alloy steels is actually a scrap conversion process in which pig iron is not so dominating as in primary steel production.

Quality of the Materials Used

Some question exists as to the type of pig iron most suitable. So many variables are involved that it is natural that no decisive opinion has been reached on this important point. The tendency is to favor iron with about 1 per cent silicon, which has sulphur well under .050 per cent. There is also a distinct preference for higher manganese than is natural with Lake Superior ores. The addition of manganese ores to carry the manganese to about 2 per cent in the iron is apparently becoming standard practice. An average of all iron from a single stack for a month showed the following analysis:

1.16 Silicon	.039 Sulphur	1.91 Manganese
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This iron had been made at the rate of 720 tons per day with 1,772 pounds of coke per ton. The average silicon

*Paper presented before the American Iron and Steel Institute at New York on May 25, 1928.

†Central Alloy Steel Corporation, Massillon, Ohio.

of 1.16 per cent for the month indicates the preference for higher silicon iron. The range might be considered as .80 to 1.20 per cent silicon with considerable preference for any variation to be toward the high side.

Considerable discussion might be made of the metallurgical effects of hot iron or cold iron. There is no outstanding metallurgical reason which indicates the necessity of remelting pig iron. There is no practical result that has proven this point essential. It, therefore, is to be expected that the economic factors so much in favor of hot metal will over-balance any group of questionable considerations. The industry is essentially dependent upon hot metal melting practice with a limited production of cold melt steels. The usual production from cold iron is limited to chemical combinations that require special iron as high-carbon low-manganese bases of peculiar sulphur requirements.

The other essential of the special steel business is the steel scrap. Our ideas of scrap requirements are hazy. We have developed some essentials, such as elimination of high-sulphur or high-silicon materials, but the actual limitations of scrap are not nearly as clearly defined as the limitations of pig iron.

Special steels are based upon the melting of heavy melting scrap. Railroad scrap might be considered the most desirable and is a standard material. It should be carefully separated into definite ranges of composition and physical characteristics; thus rail steel should be a distinct scrap, structural steel another, etc. Balanced charges designed to melt properly can only be made up of definite lots of chosen material. The study of steel scrap, its sources, its preparation with its importance to physical conditions of the finished steel, is unscientific at present. It is rather startling to find that certain special steels are only successfully made with light scrap but it may point out that definite knowledge of steel scrap can provide as definite a tool as the knowledge of pig iron or heat treatment.

The future will see very considerable attention paid to the relation of charge to final physical properties.

The auxiliary materials such as ferro-alloys, bottom materials, lime, fuel materials, etc., should be carefully inspected for more reasons than are apparent at a glance. All melting practice, whether open-hearth, electric or crucible, is actually a fine art. If the raw materials are kept very uniform, the variables are more nearly constant.

The increasing appreciation of the physical chemistry of steel melting has clearly shown that the chemist will be more useful before making the heat than in his present position as historian, recording the results.

The study of combustion of fuels, the relation of bottom materials to physical characteristics of finished material, the slag chemistry, the reactions of deoxidizing and the resultant products are all physical chemistry of the melting and refining process. At the present time they overshadow the essential iron and scrap, and in the future will be investigated even more closely.

Properties of Alloying Elements

It has been stated earlier that alloy steels are dependent upon special elements for their peculiar properties. It will be of interest to discuss the special elements involved and study the probable future combinations. A chart of familiar names involved in steel manufacture, arranged with relation to their atomic characteristics, would present the following:

Element	Atomic number	Atomic weight	Periodic group	Crystal lattice
Carbon	6	12.00	IV	
Nitrogen	7	14.01	V	
Oxygen	8	16.00	VI	
Magnesium	12	24.32	II A	Hexagonal
Aluminum	13	26.97	III	Face centered cubic
Silicon	14	28.06	IV	Tetrahedral cubic
Phosphorus	15	31.02	V	
Sulphur	16	32.06	VIA	
Titanium	22	48.1	IV A	Hexagonal
Vanadium	23	50.96	V A	Body centered cubic
Chromium	24	52.01	VI A	Body centered cubic
Manganese	25	54.93	VII A	
Iron	26	55.84	VIII	Face centered cubic
Cobalt	27	58.94	VIII	Body centered cubic
				Face centered cubic and hexagonal
Nickel	28	58.69	VIII	Face centered cubic
Copper	29	63.57	I B	Face centered cubic
Zinc	30	65.38	II B	Hexagonal
Molybdenum	42	96.0	VI A	Body centered cubic
Tin	50	118.7	IV B	Body centered tetragonal
Tungsten	74	184.00	VI A	Body centered cubic
Uranium	92	238.17	VI a	

This rather elaborate group of properties has been assembled to indicate the nature of the elements involved. It may be assumed that alloying will be simpler if the physical constants of the metals to be alloyed are similar. Iron, the essential base, has the following characteristics: It is body centered cubic from its freezing point 1,535 deg. C. to about 1,400 deg. C.; it is face centered from 1,400 deg. C. to 900 deg. C. and changes back to body centered cubic below 900 deg. C. It is thus a body centered cubic over its workable ranges except from 1,400 deg. C. to 900 deg. C. Iron may therefore be expected to alloy more naturally with body centered materials. In this group we find chromium, molybdenum, tungsten and vanadium. It may also be expected to alloy with certain face centered cubic materials and we find nickel, cobalt, copper and aluminum in this group.

A more important grouping, and in fact the only grouping significant in the commercialized aspect of production, is whether the alloying materials oxidize in melting. We observe that nickel, molybdenum and copper are stable, and chromium, manganese and vanadium are not. We thus find the commercial production alloy steels sharply divided into two groups—those in which the alloy need not be protected and those made under reducing conditions or under specific conditions of deoxidation and time element.

We may expect the oxidizing open-hearth process to be the main source of alloys of nickel, molybdenum and copper, while we would expect the chromium, vanadium and similar steels to be made in electric furnaces or under conditions as nearly neutral as it is possible to obtain in open-hearth furnaces.

Fuels and the Charge for Open-Hearth Process

The open-hearth for alloy steel is of conventional design but is usually operated on other fuel than producer gas—oil, tar, gas and liquid fuel. Probably the most satisfactory balance of fuel is coke oven gas and enough liquid fuel tar or oil to give the proper flame conditions. Liquid fuel, such as tar or oil alone, is very desirable. Small variations are encountered in various plants but no essential difference is apparent or necessary; and it may be stated that any furnace satisfactory for the making of good open-hearth steels could be used to manufacture alloy steels.

The charge when ready to tap has increased value and it is to be expected that, as insurance, certain changes would be made to secure satisfactory conditions. As a preliminary, it may be stated that the time cycle of operations is lengthened. The charge is limestone, scrap, and pig iron. No ore is charged with the lime and in fact ore is rather sparingly used in comparison to the amounts conventional in tonnage steels. This characteristic caution of guarding against over oxidation would appear at first glance as the essential difference between tonnage practice and special practice. This is further to be noted in the shaping of slags and cleaning up of heats. Minimum times from last ore addition to permit working of ore from bath are conventional.

The elapsed time from last ore feed to clean up is usually two hours and the clean up and alloy period is usually one and one-half hours more, making the elapsed time from last ore feed to tap three and one-half or more hours.

The use of burnt lime, silicon pig (both 10 and 15 per cent), spiegel and silico-manganese, pig iron or billets, for slag shaping is encountered. The selection of the proper combinations to produce proper physical characteristics is a matter of experience. The choice of material used to shape up a heat cannot be hazardous and it is customary to indicate the materials to be used in shaping and finishing the heat even more carefully than the choice of scrap used in the charge.

The requirements of producing essentially coarse-grained or fine-grained steels, steels that anneal under certain conditions, steels that machine, forge, or roll certain ways are all characteristic requirements of the industry.

It is well for the tonnage manufacturer to give thought to the specifications that have become standard for special steel producers. It is to be expected that the user of the future will desire from the commercial producer the same privilege of incorporating intangibles into the requirements. That this is the trend has been well shown in the spread of specification for carbonizing steels with intangible physical requirements. The present trends of heat treating carbon stocks is closely following the experience of the special steel maker. It is of importance to the maker of tonnage steel to recognize that the intangible physical requirements are a detriment to tonnage production and any attempt to combine will result in compromise of quality of the special and cost of the commercial. These intangibles are usually intimately associated with the finishing stage of the heat and are so intimately connected that the judgment of trained melters usually cannot be relied upon and certain specific routines are set up. The average result is safer than individual judgment.

The finishing stages of the heat are usually carefully checked by chemical methods, but the bulk of the work remains for skilled melting practice. The alloy heat is usually run at higher temperatures than commercial steels. The clean up is more thorough and type of clean up selected with relation to final use.

Additions of the Alloy Elements

Nickel and molybdenum do not oxidize and may be added at any stage of the heat. Conventional practice would be to add nickel as pig iron with the scrap, while the molybdenum is added after melting as ferro-molybdenum or calcium molybdate. The oxidizable alloys—chromium and manganese—are added after de-

oxidation through the slag in the furnace as ferro-chrome and ferro-manganese.

The vanadium, silicon and aluminum are added to the stream as it leaves the furnace going into the ladle.

Procedure in Other Processes

In the other major process, the arc electric, the production of alloy steels is in its essentials on the same basis as the open-hearth. The best practice of making the carbon steel base is only proper insurance against loss of the added alloys. Usually the process is cold melt. This is not essential but practically the results favor cold melt and it is the conventional methods for general production.

The charge of scrap is melted, the heat slagged off, the final slag made up and the shaping of the heat is carried out. Since the value of the material is usually high, every effort possible is made to produce as high grade material as possible. The finishing stages of the heat are usually under carefully shaper carbide slags. The alloy additions are made under specific conditions. This is important since the electric steels are usually so delicately balanced that the slightest deviation from routine is apparent in the final product. This is apparent in the manufacture of chromium steels and is especially noticeable in high-chromium types, such as stainless steels.

Both the major processes—open-hearth and electric—deliver from the furnace sufficient metal to make the operation of teeming a very important factor in the production. To the writer the pouring of steel has always seemed the orphan of the steel business. Our physical chemists have studied the reactions of the blast furnace. We have some information concerning our open-hearth conditions and at present are developing much more. We study our heating, rolling and treating. We can get direct expressions from mill men or metallurgists on nearly any phase of the steel business with the single exception of ingot casting. The factors of temperature, nozzle size, pouring speed, mold design, solidification rate, sinkhead design and their relation to the various chemical compositions are very vague. Individual plants specializing in ingot casting have made some progress but in general less specific information exists on this point than on any other.

Teeming Practice and Mold Design

Alloy steels are almost without exception killed steels. As such they are cast in sinkhead ingots. Considerable tonnage is cast in the big-end-up ingot, probably best typified by the Gathmann type of ingot mold. The sinkhead design varies, but for the rolling type of ingots may be considered standard as typified by the Turner brick top mold. The volume relation of sinkhead to ingot varies slightly, but is nearly 15 per cent of the gross volume of the liquid steel.

Mold design varies from plant to plant, but an increasing proportion of fluted ingot for special steels are encountered. The larger ingots for forging work are almost all fluted, although size may prohibit the big-end-up type. Conventionally a special steel may be said to be poured into a big-end-up mold whose walls are not thick, top area of mold to ingot is about $1\frac{1}{2}$ to 1, or 1 to 1, while the bottom area of mold to ingot will approximate 2 to 1. The length below the sinkhead may be three times the diameter. The length-diameter ratio even at 2 to 1 is questionable, but it is hardly practical to work such short ingots into billets. The sinkhead usually provides for considerable metal

in excess of the pipe cavity requirements, but low efficiency must be faced to permit sufficiently rapid freezing to eliminate undue carbon segregation immediately under the sinkhead. The entire ingot design is on a scale very small compared to commercial steels. Conventional ingots would be 20 in. diameter, weighing gross less than 5,000 lbs. In fact, any ingot in excess of 7,000 lbs. gross must be considered large.

Extremes of care in pouring are well repaid. The ingot surfaces of special steels are unquestionably supersensitive and all precautions of clean molds and proper pouring practice are amply repaid in freedom from defects.

The problem of freezing time, or period after pouring before stripping, while interesting is usually insured by the fact that the conventional ingot solidifies comparatively quickly, due to its small size. One and one-half hours after pouring the 20 in. ingot is practically solid. The time of removal of sinkheads, stripping, usually insures solidity before charging.

Heating and Rolling Into Blooms

The varied composition of alloy steels imposes on the rolling mill crew the definite routine of rolling from predetermined temperatures. The rate of conductivity is low and the heating time is long. These factors are usually cared for by providing experienced optical pyrometer operators to furnish temperatures to heaters both at pits and at bar mill furnaces. Specified time temperature cycles are furnished the heaters with the rolling order. These are checked and the 400 deg. F. variation encountered daily in the various special alloy rolling indicated to the heaters. This method has found favor with the heater, since it insures him assistance in establishing himself without watching each lot during the rolling in order to judge temperature.

The blooming mill operations differ from those for commercial steel in that smooth rolls are essential. In the ingot of the future, where the skin will stand more punishment, ragged rolls may be used, but under present knowledge of the art the smooth roll is essential. Reductions are lighter due to both lack of ability to bite the ingot and for the protection of the material. About double the number of passes on the mill are used in breaking down from ingot to bloom.

The preliminary working breaks up the ingot structure and the subsequent rolling can be carried out under nearly normal commercial rolling practice. The absence of ragging is conventional at all stages.

Alloy steels are, commercially speaking, not capable of being fire welded. The skin of the ingot is sensitive and when broken the rupture has no tendency to heal. Every break in the surface means a defect to be removed from the billet prior to rerolling or forging. This is done in the same manner as in commercial steels by chipping or grinding. The requirements are somewhat more exacting, due to the intangible physical characteristics. It may be expected that the commercial steel user of the future will demand the same standard, in fact he does at present.

Problems of Finishing Mill Operations

The prepared billets are converted, as mentioned before, in mills of about the same layout as commercial bars. The increased value justifies certain precautions and occasional combinations of chemical composition require radical departures in roll pass design. On the whole, the most serious problem is the wide variation

of sizes that must be produced and the extremely small average quantity. An investigation covering some of the larger plants would indicate that the average tonnage order of alloy steel is less than ten tons. This entails a multitude of roll changes. The small average size of an order, coupled with the wide variations of characteristics, entails considerable scrap loss in starting orders. It explains the position of the older type of bar mills which have held their ground in the industry by their ability to handle small items.

To properly handle orders which are taken to fill special requirements involves certain precautions not customary in commercial steel manufacture. The average requirement of commercial steel orders can be properly specified without elaborate precaution and usually the material can be inspected prior to shipment and its stability to meet conditions guaranteed.

In the special steel requirement the test of satisfaction is usually vague. The user is actually fair, but unable to state his requirements. He desires a certain set of conditions complied with, is willing to furnish all facilities for observation of his manufacturing operations, is usually very patient to experiment, but asks that steel be supplied that will do a certain job. The test of the material is usually satisfactory life. This may mean one race for an automobile crankshaft or 20 years service for a locomotive part.

To provide this information men who act as interpreters study the customer's requirements and see that proper instructions follow the order into the production departments. These men are usually trained steel workers, often with technical training. They must be reasonably familiar with the details of the production and skilled in many branches of manufacture.

Peculiarities of Specifications

Each order, as it enters the operations, must be passed upon, the proper set of instructions issued to all parties, the proper tests instituted and recorded as progress is made, the final assembly of all the information surveyed and the material released for shipment.

As an example, we might mention an order for bar stock for differential gear forgings. The order may read as simply as "Ten tons of 2 in. Rd. S. A. E. 2315." The intangibles of this specific order may be as follows: "Two inch round S. A. E. 2315, for John Doe & Company, is regularly used for spiral bevel driving pinion on model X. Forging produced by upset process; bar ends make smaller gear; size must be accurate; length important but not vital. Chemistry must be low aim carbon 0.11 to 0.14. Stock will be checked for McQuaid-Ehi rating, two to five desired. Stock will be checked for non-metallic inclusions by microscope and evenness of structure by hot acid etch, and must cut and harden satisfactorily."

All this material is produced, checked, shipped and upon arrival at destination is tested. Some startling variations of interpretation of requirements can and do arise. The teeth may twist too much or too little, the finish may be unsatisfactory, the number of pieces per grind of tools may be unsatisfactory. These problems are very real. An instance can be cited of production being tied up because a $\frac{3}{4}$ in. hole in an oil hardened gear, closed in .002 in. more than the steel from another source, thus requiring absolute separation of the two steels during manufacturing operations.

(Continued on page 778)

Basic Open-Hearth Practice*

History of Process Briefly Covered—Production in the Three
Leading Countries—Flexibility of Process as Regards
Charge and Output—Maintenance of Supremacy

By G. B. WATERHOUSE†

THE basic open-hearth process of steel making is so called because it is carried out in an open-hearth furnace, the laboratory or hearth of which is lined with a basic refractory material. This enables basic slags to be used, which is essential for the methods of refining employed.

The metallic charge usually consists of various kinds of scrap steel coming from the rolling mills, the railroads, and every industry using steel, together with either solid or liquid pig iron. Iron ore is almost always used for its effect during the working of the heat, and towards the end of the operation various ferro-alloys are added either in the furnace or the ladle. In reckoning the metallic charge it is now customary to include the metal entering the charge in any of these ways. The main slag-making material is limestone, of the proper analysis, generally charged at the beginning of the heat, with burned lime available for addition during the working of the heat. Some important modifications of the basic open-hearth process use burned lime exclusively. A material used during the working of the heat, for its effect on the slag, is fluorspar or calcium fluoride, the majority of the fluorspar mined going to the basic open-hearth industry.

The process is usually carried out in stationary furnaces. The hearth is put in proper shape following the tapping of the previous heat, the tap-hole is made up and charging is started by spreading a little light scrap over the bottom by means of the charging machine. On top of this is placed the limestone and such iron ore as is introduced with the charge, followed by the rest of the scrap. This generally constitutes 40 to 50 per cent of the metallic charge. If cold pig iron is used it is charged after and on top of the scrap, but the majority of basic open-hearth steel is made from scrap and liquid pig iron. This liquid pig iron is not added until the scrap has been thoroughly heated through and at least partially melted. It is then brought from the pig iron mixer or direct from the blast furnace and poured through a short charging spout into the furnace. Shortly after its addition the slag in the furnace froths up and foams and it is common practice to allow much of this slag to run through a tap hole on the pit side of the furnace into a slag box. This is often referred to as a run-off slag. It is fairly high in silica, iron and manganese, relatively low in lime, and is usually rather high in phosphorus. Following the addition of the liquid pig iron the heat is all brought to the molten condition as rapidly as possible, when it is known as clear melted. About this time, in normal heats, the limestone, which has been largely changed to lime, rises to the surface of the bath, a phenomenon known to the furnace man as "the lime coming up." Refining now begins and the heat is "worked" until it is in proper shape to tap, which means that the slag is of proper consistency and the bath of steel of the right composition and temperature. The required final additions, usually of ferro-alloys, are made

either in the furnace, or partly in the furnace and the ladle, or else all in the ladle while the steel is being tapped from the furnace, after which the steel is poured into ingots. With stationary furnaces everything is usually tapped from the furnace, neither slag nor steel remaining, and the hearth is made ready for the next heat. The usual time of an ordinary heat is from eight to twelve hours or more.

History of Process

It would be interesting if there were time to go into the history of this important process. The furnace was designed by William Siemens in England and an early method of carrying out the usual steel-making process was developed by the brothers Martin in France. For this reason the process is generally known abroad as the Siemens-Martin process. One man's name should not be forgotten, namely, Sydney Gilchrist Thomas. This young Englishman developed the basic hearth or lining for both open-hearth furnaces and bessemer converters and the basic open-hearth process is greatly indebted to him. The story of his short life is very interesting and would be a great inspiration to all young men starting in the steel business. Although hard to obtain, it may be found in the larger libraries, and is recommended to all interested in the basic steel making processes.

As pointed out by Mr. F. L. Toy,* the first basic open-hearth steel made in this country was probably that produced at the Bay State Iron Works, South Boston, in 1869, working on a hearth of calcined dolomite. The father of one of my associates, Prof. W. A. Johnston, worked at this plant. He remembers his father's conversations about their difficulties, chiefly concerned with roof troubles, the proper burning of the gaseous fuel and obtaining the required high temperatures. Mr. Toy also mentions the first production of basic open-hearth steel on a large commercial scale which was at the Homestead Works of Carnegie, Phipps & Company, in March, 1888. It is interesting to note that the general superintendent of the plant at that time was our president, Mr. Charles M. Schwab.

The process has now developed to be the most important steel-making process, not alone here but in most countries. This paper is devoted to a development of this theme along three directions:

- 1—To point out that the basic open-hearth process is the most important of the steel-making processes.
- 2—To discuss briefly some of the reasons for this.
- 3—To point out some of the methods by which this standing can be maintained.

Present Position of the Basic Open-Hearth Process

The best way of bringing out the present position of the basic open-hearth industry is by means of statistics, and in the appendix are given tables of the steel production of the United States, Great Britain, Germany and France since 1900. These statistics are either from the

*Paper read before the American Iron and Steel Institute, New York, May 25, 1928.

†Professor of Metallurgy, Massachusetts Institute of Technology.

*The Basic Open-Hearth Process, Francis L. Toy, Yearbook, American Iron and Steel Institute, 1920, p. 319 and sq.

Statistical Bulletins of the American Iron and Steel Institute, or have been collected from various sources by Dr. H. H. Cook, assistant secretary of the American Iron and Steel Institute. Table I gives the figures for

TABLE I—Production of Steel Ingots and Castings in the United States, 1900-1927, in Gross Tons.

Year	—Open hearth— Basic	Acid	Bessemer	Total of all processes	Per cent basic O.H. to total
1900	2,545,091	853,044	6,684,770	10,188,329	24.9
1901	3,618,993	1,037,316	8,713,302	13,473,595	26.8
1902	4,496,533	1,191,196	9,138,363	14,947,250	30.0
1903	4,734,913	1,094,998	8,592,829	14,534,478	32.5
1904	5,106,367	801,799	7,859,140	13,859,887	36.8
1905	7,815,728	1,155,648	10,041,375	20,023,947	39.0
1906	9,658,760	1,321,653	12,275,830	23,398,136	41.2
1907	10,279,315	1,270,421	11,667,549	23,362,594	43.9
1908	7,140,425	696,304	6,116,755	14,023,247	50.9
1909	13,417,472	1,076,464	9,330,783	23,955,021	56.0
1910	15,292,329	1,212,180	9,412,772	26,094,919	58.6
1911	14,685,932	912,718	7,947,854	23,676,106	62.0
1912	19,641,502	1,139,221	10,327,901	31,251,303	62.8
1913	20,344,626	1,255,305	9,545,706	31,300,874	64.9
1914	16,271,129	903,555	6,220,846	23,513,030	69.2
1915	22,308,725	1,370,377	8,287,213	32,151,036	69.3
1916	29,616,658	1,798,769	11,059,039	42,773,680	69.2
1917	32,087,507	2,061,386	10,479,960	45,060,607	71.2
1918	32,476,571	1,982,820	9,376,236	44,462,432	73.0
1919	25,719,312	1,229,382	7,271,562	34,671,232	74.1
1920	31,375,723	1,296,172	8,883,087	42,132,934	74.4
1921	15,082,564	507,238	4,015,938	19,783,797	76.2
1922	28,387,171	921,812	5,919,298	35,602,926	79.7
1923	34,665,021	1,234,636	8,484,088	44,943,696	77.1
1924	30,719,523	857,827	5,899,590	37,931,939	80.9
1925	37,087,342	947,146	6,723,962	45,393,524	81.7
1926	39,653,315	1,038,664	6,934,568	48,293,763	82.1
1927	37,144,268	924,067	6,191,727	44,935,185	82.7

From the Annual Statistical Reports of the American Iron and Steel Institute.

Fifth column also includes steel ingots and castings made by the crucible, electric and miscellaneous processes.

the United States and in the last column is given the percentage of the basic open-hearth ingots and castings to the total produced by all processes. In 1926 with a total steel production of 48,293,763 tons this percentage was 82.1 per cent; in 1927, with total steel production 44,935,185, it was 82.7 per cent.

From these tables has been constructed the diagram, Fig. 1, which shows what percentage the basic open-hearth tonnage is of the total tonnage produced each year from 1900 to 1926 in the cases of the United States, Great Britain and Germany. To consider our own country first, the percentage has steadily risen from 25 per cent in 1900 to more than 82 per cent in 1926 and 1927. It has been more than 80 percent for the last four years, so that more than four-fifths of all the steel we make is produced by this process.

In the case of Great Britain the percentage has risen from 7 per cent in 1901 to a maximum of 64.2 per cent in 1925, dropping slightly in 1926 to 62.8 per cent. Since 1921 it has been about 60 per cent or above. A brief consideration of the tonnage figures for Great Britain is interesting. The rise in basic open-hearth percentage has been at the expense of the acid open-hearth and the bessemer processes. The basic bessemer has apparently ceased to be a producing process and the acid bessemer has a very moderate output.

The third curve of Fig. 1 shows the percentages for Germany. This curve does not show the steady rise noted with the United States and Great Britain, but there has

been a marked increase since 1920. More than 50 per cent of the steel made in Germany is made by the basic open-hearth process. In 1923 the percentage was 63 per cent but in the last few years appears to be somewhat stabilized at 53 to 54 per cent. It must be remembered this is for ingots alone; if castings made by this process could have been included, the percentage would have been higher. Judging from the table in the appendix, the acid bessemer has practically ceased to be a producing process. The acid open-hearth produces a very small tonnage, the only real competitor of the basic open-hearth being the basic bessemer, and the former has definitely won the battle for supremacy.

Unfortunately a similar percentage curve for France could not be prepared but the tonnage table in the appendix supports the conclusions that the production curve for basic open-hearth steel is rising in France, but that the basic bessemer is still the predominant process.

Reasons for the Supremacy of the Basic Open-Hearth Process, Particularly in the United States

In order to supplement the conclusions of the first part of this paper, it may be well to consider some of the reasons for the supremacy of the basic open-hearth process, particularly in the United States. One of its outstanding advantages is the ability to deal with raw materials that vary greatly in chemical composition, particularly as to the amount of phosphorus contained. This is well known and the exhaustion of much of the low-phosphorus iron ores has required methods that will make good steel from pig iron with varying amounts of phosphorus above the bessemer limit. For many years the basic open-hearth process was considered to be the method by which to handle raw materials that lay between the acid bessemer limit of phosphorus and the limit for basic bessemer practice, but it is now being increasingly recognized that this process through certain modifications can successfully handle pig iron very high in phosphorus. Also, by

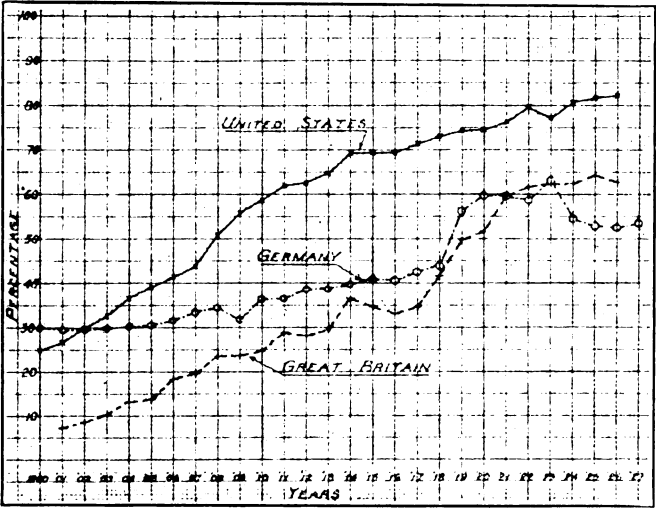


FIG. 1—Chart showing percentage of basic open-hearth steel to total steel production in United States, Great Britain, and Germany during period, 1900-1927.

proper working, a high-phosphorus slag can be prepared and separated that will compete with basic bessemer slag, as is pointed out and described in Mr. W. A. Forbes's* recent paper before the Institute.

*Technological Problems of the Steel Industry, W. A. Forbes, Yearbook, American Iron and Steel Institute, 1927, p. 286.

Another reason for the growth of the basic open-hearth is the well-known ability of this process to successfully deal with the large amounts of scrap that have to be re-worked into good steel. This scrap varies greatly in kind and composition and the subject has been well handled in papers† presented before the Institute. However it is not so generally recognized how flexible this process is in regard to the percentage of scrap that can be in the charge. Depending upon the amounts of pig iron and scrap available and economic conditions, also to some extent upon the kind of steel that is to be made, the percentage of scrap can vary from 100 to 0 per cent. It is true the amount of scrap usually runs about 40 to 50 per cent, but there are plants that have regularly used far higher scrap percentages than this, while certain modifications of the basic open-hearth process operate most successfully when very little or no scrap is used. This flexibility in regard to the kind of metallic charge has added to the growth of the process.

A brief mention should also be made of the size of the furnaces. This can vary over very wide limits, much wider limits than is generally supposed. Furnaces of small capacity are operating successfully, even down to ½-ton size. There is a so-called 1-ton furnace running with splendid results in a plant near New York. From this small size, stationary furnaces range in all capacities up to the big Weirton furnaces generally called 250-ton capacity, but often tapping two heats together weighing 300 tons. The rating of the furnaces varies with many conditions, a given furnace having considerable flexibility. One-hundred-ton stationary furnaces are now very common and this size furnace is more or less of a standard. The so-called Talbot, tilting or rolling furnaces are built in many sizes from those of moderate capacity up to furnaces holding more than 300 tons. One such furnace in the Pittsburgh district usually gives three 100-ton heats that follow each other as quickly as the ladles can be brought to the furnace. This variation or flexibility in capacity with the possibility of meeting plant requirements in regard to amount of steel needed, construction and plant costs, is another strong reason for the growth of this process.

Kinds of Steel by Process

Attention should also be drawn to the great variety and kind of steels successfully made by the basic open-hearth process. In regard to carbon percentage open-hearth steels cover a very wide range. On the low side we have material with practically no carbon, often called ingot iron, then the large tonnage of rivet steels and sheet steels very often with less than .10 per cent, the next great class is probably structural steel with carbon varying from about .15 to .30 per cent. Many forging steels have from .35 to .45 per cent carbon. Rail steel, of which about 3,000,000 tons is made each year, varies from about .60 to .90 per cent, and spring steels and steels for special purposes are made with carbon reaching as high as 1.4 per cent in some cases. It is a remarkable range of steels, but this does not tell the whole story because it does not include many special steels nor the alloy steels. With the exception of tool steels, such as the high-speed steels, and certain of the alloy steels, such as high-silicon steels for transformer sheets, or the high-chromium "stainless" steels, most of the alloy steels are successfully made in basic open-hearth furnaces. A list of such steels would be impressive. It would include nickel

steels, chrome-nickel, vanadium steels, chrome-vanadium, molybdenum, chrome-molybdenum and many others, as well as special steels not often thought of as alloy steels, such as the high-silicon structural steels which now contain up to 1 per cent silicon, the steels with manganese up to 2 per cent and above, etc. This flexibility of the process in regard to the kinds of steel that can be successfully made has necessarily contributed to its growth.

In common with the acid open-hearth process a great variety of fuels can be used. Producer gas is still the main fuel for the basic process, natural gas is still a favored fuel when it can be obtained, and coke oven gas is being used in increasing amounts. In Germany mixtures of blast furnace gas with coke oven gas are being successfully used. Liquid fuels such as fuel oil and tar are used a great deal. Powdered coal has been experimented with considerably but is not being used as a standard fuel. The producer gas is being made from a large number of solid fuels. One plant in Sweden reported it was operating successfully on sawdust and wood waste burned in producers. All kinds of coal have been used, lignites, the various qualities and kinds of bituminous coal, and anthracite. The process is not dependent on one kind of fuel.

The various fuels now being used in this country may be illustrated by the following figures taken from a table in Mr. Forbes' recent paper* before the Institute. His table gives the proportion of the open-hearth steel ingots and castings made in various years by an important steel interest according to fuel used. His figures for 1926, in order of importance, are:

	Per cent
Producer gas	40.6
Coke oven gas and tar	40.6
Coke oven gas and natural gas	13.1
Tar alone	10.6
Coke oven gas, natural gas, tar and fuel oil....	6.2
Coke oven gas, tar and fuel oil.....	3.9
Coke oven gas alone.....	3.8
Fuel oil alone	2.7
Natural gas alone	2.7
Tar and fuel oil	.7
	100.0

It may finally be pointed out that the process can be successfully combined with other methods of steel making. For instance, under certain economic conditions, together with a plentiful supply of liquid pig iron, the combination of the acid bessemer process with the basic open-hearth is to be recommended. This is usually spoken of as the Duplex process, the steel being marketed as basic open-hearth steel. The annual output in the United States is probably somewhat in excess of 3,000,000 tons, almost all grades of steel are made except alloy steels, and the quality is first rate.

Methods by Which this Supremacy can be Maintained

One of the main methods now being used to maintain this supremacy of the basic open-hearth process is to keep conversion costs low and make every effort to reduce them. This is being striven for in many different ways and a few of them may be briefly touched upon.

The refractory question is a very vital one to the basic open-hearth industry and one phase of it has somewhat escaped general attention, namely, the widespread and

†Iron and Steel Scrap, E. J. Lowry, Yearbook, American Iron and Steel Institute, 1924, p. 367 and sq.

*Technological Problems of the Steel Industry, W. A. Forbes, Yearbook, American Iron and Steel Institute, 1927, p. 275.

increasing use of "prepared dolomite" for refractory purposes, particularly hearth repairs. Dead burned magnesite, imported from abroad, is still the standard material for putting in new bottoms. The main sources of supply are Austria and Czechoslovakia. The United States Bureau of Mines reports that 77,108 short tons of this material was imported in 1926 and 49,873 in 1927. From the Mineral Resources of the United States and Mineral Industry it would appear that the dead-burned magnesite produced and imported was 84,665 short tons in 1924, 71,730 in 1925, and 119,648 in 1926.

Each year sees an increasing amount of "prepared dolomite" being used at the expense largely of this imported magnesite and of single-burned dolomite. Some of the trade names of this prepared material, arranged alphabetically, are: Kendymag, Magdolite, Magnefer, Magnite and Syndolag. A good deal of this class of material is being used. No accurate figures are collected but estimates of those qualified to judge believe a low figure of 200,000 short tons, annually, is correct, and that it may be as high as 300,000 tons annually. It is prepared from carefully quarried dolomites of suitable composition, crushed and mixed with some desired fluxing agent that will unite with the dolomite during burning and reduce the tendency of the burned dolomite to slake. Powdered coal-fired rotary kilns are used for burning, in some cases vertical kilns are used for a preliminary burning followed by treatment in a rotary kiln. The clinker is often crushed and screened and the fines returned to the circuit.

No separate analyses will be given. The lime content is usually from 50 to 55 per cent; the magnesia is approximately 35 per cent but in many cases approaches 37 or 38 per cent. The iron oxide, silica and alumina together vary from a total of 7.5 to 12 or 14 per cent, depending on the purity of the dolomite used and to the theories of the several manufacturers as to the most advantageous flux contents. The loss on ignition is always low, very often less than 2 per cent or even 1 per cent, because these products are thoroughly burned.

This already has the status of a live and active industry. Constant efforts are being made to improve the product by improving the methods of manufacture and by research into the various compounds produced in the prepared dolomite during its burning and production.

The question of the amount of fuel consumed in the basic open-hearth process is constantly receiving a great deal of attention. There has been a splendid series of papers presented before the Institute, starting with Mr. Whigham's paper in 1913, dealing with the questions of the various fuels used, port design, regenerator design, waste heat boilers, gas producer practice, thermal efficiency and studies of the heat balance of the process. Fuel problems were gone into rather fully in Mr. Forbes' paper, last October, so need not be considered here. However, mention should be made of the fact that coke oven gas alone is being successfully used. More of it is becoming available from year to year. A battery of coke ovens is being built at one steel plant that will be heated with blast-furnace gas so that all the coke-oven gas will be set free for other uses. The use of this fuel for the open-hearth furnace will simplify certain features of design. No regenerators are needed nor should be used for the fuel, and the port design will approach that used for another high value gaseous fuel, natural gas.

(To be continued)

The Chapman-Stein Company

The Chapman Engineering Company and The Chapman-Stein Furnace Company, both of Mt. Vernon, Ohio, have recently merged their operations and personnel under the name of The Chapman-Stein Company, Combustion Engineers.

It was in 1920 that the Chapman-Stein Furnace Company was organized and launched by The Chapman Engineering Company. Since that time the Furnace Company has done a successful and rapidly expanding business in the engineering and construction of industrial furnaces for the steel and glass trades. Messrs. Charles M. Stein & Company of Paris, have until recently owned 50 per cent of the Furnace Company's capital stock. A few months ago, however, The Chapman Engineering Company purchased the French company's interest and thus came into possession of the entire capital stock of the Furnace Company. With the two companies unified as to ownership and working in the same field of engineering, it was a most logical step to merge their operations and effect the economies which usually follow.

The personnel of the enlarged company has remained practically unchanged, the executive officers being as follows: B. B. Williams, President; George R. McDermott, Vice President and General Manager; N. L. Daney, Treasurer; Z. E. Taylor, Secretary; all of Mt. Vernon, Ohio, who with William B. Chapman, of New York, form the Board of Directors.

The enlarged company will continue to broaden its service in the field of combustion engineering, giving special attention to the sale of gas producers, industrial furnaces and all allied equipment, including the installation of waste heat boilers for metallurgical furnaces and the construction of complete producer gas plants.

The company owns important patents relating to metallurgical furnaces, gas producers and allied equipment, the European rights to which are being successfully exploited by Charles M. Stein & Company of Paris and, throughout the British Empire, by the Stein-Atkinson Company, Limited, of London.

Schwab Given Bessemer Medal

The Bessemer Gold Medal presented to Charles M. Schwab in London on May 3, 1928, is awarded annually by the British Iron and Steel Institute from funds left in trust for that purpose by Sir Henry Bessemer, inventor of the steel-making process which bears his name. In 1873 Sir (then Mr.) Henry Bessemer invested the sum of £400 in perpetual debentures in the London, Midland and Scottish Railway to procure this medal to be awarded at each of the annual meetings of the Institute for distinguished merit in promoting the metallurgy of iron and steel. The Council of the Institute may award the medal either to members or non-members of the Institute. Mr. Schwab is an honorary vice president of the British Iron and Steel Institute, having been elected to that office following his election to the presidency of the American Iron and Steel Institute to succeed the late Judge Gary.

The strict conditions laid down to govern the awards of the Bessemer Gold Medal may, at the discretion of the Council, be so interpreted as to include persons through whom the iron and steel trades have been substantially benefited.

Sheet Steel for Automobile Bodies

Sheet Mills and Hot Rolling Practice in Making Black Sheet from
Sheet Bar—Defects Arising in Hot Rolling—Influence of Hot
and Cold Work on Structure and Properties of Sheet Steel

"AUTOSHEET"

PART IV

SHEET bar, as cut on the bar mill shears, are reduced to the specified gage or thickness, length and width by mechanical refinement on rolls known as hot mill rolls. This refinement is essentially a reheating of the bars and a preliminary reduction to about one-half their specified length on breakdown or roughing rolls followed by another reheating and finishing to size on the finishing rolls. The resulting sheet is known as a "black sheet" and is suitable for automobile body stock only after such subsequent refinements as cold rolling, pickling and annealing.

This mechanical refinement by hot rolling to size from the bar takes place in the hot mill department which is made up of a series of hot mill units. These units in turn usually consist of two stands of rolls—one the breakdown stand and the other the finishing stand each having two-high non-reversing rolls. In conjunction with these two stands are two heating furnaces one of which is called the "pair furnace" which reheats sheet bar for the breakdown rolls while the other is called the "sheet furnace" which reheats the breakdown sheets for the finishing rolls. These furnaces are about twenty feet away from the rolls on the feeding or charging side while a space of about thirty feet wide is allowed on the delivery or opposite side of the rolls for piling hot finished sheets where they can cool before shearing to the size ordered.

A great many of the older sheet mill plants carry only a few units such as described above in one line or "train" and very often have a few stands for cold rolling at the end of the train. This train is then driven by

wheel usually is connected to the motor. As many as three, four and even five units (six, eight or ten stands) can be satisfactorily worked on a set-up of this nature. A complete train with its attendant pair and sheet furnaces is best summarized in Fig. 1.

Mechanical Features of Hot Mills

Before a discussion of the refinement of the bar takes place it might be well to briefly explain some of the outstanding mechanical features of the breakdown and hot finishing rolls as illustrated in Fig. 2. Each stand consists of two rolls, the bottom roll being driven while the upper roll runs loose in its bearings and is revolved by the friction of the bar or sheet passing between it and the lower roll or its friction on the bottom roll when running idle.

The rolls in any one stand are of course the same size but in different stands these rolls may vary in size, from 22 to 32 inches in diameter and from 30 to 60 inches in length. It is generally considered that the roll should be about six inches longer than the width of the widest sheet the mill is expected to roll. Thus a sheet whose specified width is 54 inches will be rolled on a 60 inch mill. Only recently are sheet mills going into rolls longer than this and at present certain sheet manufacturers are rolling 66 inches wide which, according to the above statements, will require a 72 inch roll. This demand for wide sheets is the outgrowth of competition among the automotive trade wherein they stamp a combination of two stampings, from one sheet instead of making it from two stampings made from two separate sheets.

Another very important factor that is forcing the sheet manufacturer to install larger rolls is the continuous sheet in wide widths as rolled on a strip mill basis. Competition is the spice of industrial life and the advent of continuous sheet together with automotive competition is forcing the sheet manufacturer to radically change his equipment.

The rolls thus will vary in length and diameter as described above and are set up in housings which are large cast iron supports bolted to a concrete base or mill pit over which the rolls turn. As noted in Fig. 2 these housings are closed at the top thus making them rigid which is necessary for an accurate setting of the rolls. These housings hold the rolls in place by bearings which fit into the side or "window" of the housings.

The bearings for the bottom rolls are heavier than those for the top rolls which have side bearings which keep the top roll in line with the bottom roll. The main bearing for the top roll rests on its upper side, thus allowing the mill screws to directly exert a varying pressure or draft through it onto the bar or sheet rolled. This pressure or draft is brought about by two screws which pass through the two top centers of the housings.

A glance at Fig. 2 will indicate that the operating of the screw on the breakdown is radically different from that of the hot finishing rolls. The breakdown rolls (to the right in Fig. 2) carry a beveled gear at the top of

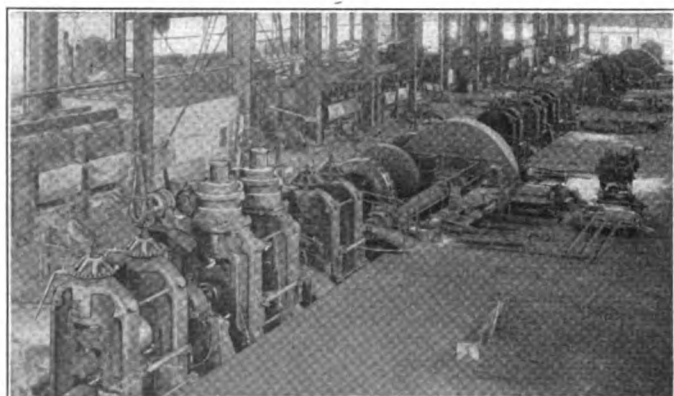


FIG. 1—Roll train and furnaces.

power connected directly to the line shaft with a heavy flywheel to prevent stalling of the rolls under peak loads. A more modern arrangement is a separate drive or department for the cold rolls, the hot rolls being driven by an electric motor geared down so as to turn the main drive of the train between 30 to 40 revolutions per minute. This motor drive is placed in the middle of the train thus lessening the torque on the main drive shaft and maintaining a steadier rotation of the rolls. A small fly-

each screw which in turn is meshed with a smaller gear and shaft extending from one housing to the other. This shaft in turn is connected to a large hand wheel or motor drive and it can be readily noted that this allows a considerable range through which the top roll can be forced up when sheet bar are going through the rolls.

An average of $\frac{1}{4}$ to $\frac{5}{8}$ inch spread is necessary in order to break down the sheet bar to a thickness which will allow finishing to the gage desired on the hot finishing rolls. Unless this quarter to five-eighths inch spread is allowed in breaking down sheet bar it would internally crack the roll resulting in its ultimate breaking.

On the hot finishing mill (to the left in Fig. 2) the screwdown is brought about by a short arm or lever, one end of which is fastened to the top of the screw. The lever is bent so as to fall into one of the notches or slots of a wheel or set screw. As there is a similar lever on the opposite screw they are usually connected by a bar called a "spanner bar" which causes both to work together and exert the same pressure on the roll through both screws. The maximum swing these levers can make is not over 90 degrees or a quarter turn of the screw which means about a quarter inch raise or "spread" on the top roll. Thus the sheet bar is broken down on rolls which have a sufficient spread to carry them through and are finished to the gage desired on rolls whose maximum spread is about one-quarter of an inch.

Method of Warming-Up the Rolls

The rolls themselves are worthy of note. They are usually chilled cast which gives about a $\frac{7}{8}$ to 1 inch chill on the outer surface of the roll and allows for polishing and dressing for some time before running into the coarse grainy structure on the inside which means a discard of the roll. Both the breakdown and finishing rolls are chilled although there are still a few instances where the breakdown is a soft or unchilled roll.

Usually the roll is received in a rough casting and is turned or dressed down to the desire diameter at the sheet mill. In doing this the roll is turned slightly concave in the center to allow for its expansion as the roll gets hot. As no water is used on this roll, due allowance must be made for this expansion.

In starting up a hot mill roll at the beginning of the week very narrow widths of iron are used which not only slowly warm up the roll but prevent imperfect sheets. If the mill started cold on wide sheets we would have a heavy center in the sheet with buckling along the edges and possibly run a big chance of cracking the roll. Hence we have an eight hour turn—the first turn of the week, which warms up the rolls by making narrow widths of iron.

Gradually the widths of the sheets are increased until the rolls are running sheets of the maximum width and the roll has an internal temperature of about 600-700 deg. F. The heat of the roll is determined by its color which would be a deep purple-brown or dark blue for these temperatures. Colors are often misleading as they are simply reflections of oxides on the surface of the roll. As temperatures of rolls are often misinterpreted under these conditions, it is best to estimate a roll's temperature immediately after the sheets have been pulled through when there is a minimum amount of oxide present on the roll. A roll running idle will start to accumulate oxides which rapidly changes its color. In general, the breakdown rolls run around 550 deg. F. with the finishing mills about 100 deg. F. lower.

About the middle of the week the widest iron is being run and the rolls have expanded to a point where the concave center is level with the end of the rolls thus passing sheets between them having a more or less equal thickness from edges to center. Occasionally the rolls get too hot, "puff" out in the center and part of the heat has to be withdrawn by turning a jet of steam against the middle of the bottom roll. After the maximum width has been reached we gradually taper the sizes again thus slowly cooling the roll until we are back to narrow widths

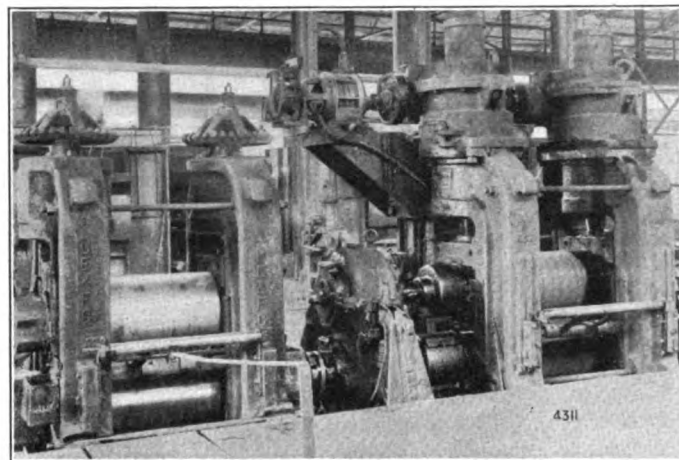


FIG. 2—Finishing and roughing stands.

of iron at the end of our week or schedule. Thus the rolls are gradually heated and cooled with a minimum risk of cracking them by too rapid an increase in heating or cooling.

Pair and Sheet Furnaces

As a general rule each of the rolling stands are provided with a furnace one of which, as previously mentioned, is the pair furnace which reheats the sheet bar for the breakdown rolls while the other is the sheet furnace which reheats the breakdown or roughed sheets for the finishing rolls.

These furnaces are simple in construction, being of the reverbertatory type with its heating chamber practically square. In back of this heating chamber is the combustion chamber separated from it by a high bridge wall over which the flame passes. The construction of the pair furnace and sheet furnace are practically alike and will be discussed as one.

The combustion chamber of both furnaces will vary in size according to the fuels used which usually are powdered coal, oil or gas. If gas or oil is used the combustion chamber is narrow into which the gas is introduced while powdered coal requires a slightly larger combustion chamber.

The floor of the heating chamber is corrugated brick which allows the hot gases to get under the bar or sheet thus causing all outer surfaces to be evenly heated. The exit flues are usually at the front end of the furnace thus preventing a suction of air through the front doors which might scale the steel. As it is very essential that the bar or sheet be free from scale it is necessary to have incomplete combustion of the fuel which keeps the sheets under a reducing atmosphere.

Compared with other furnaces used in the manufacture of sheet steel the temperatures used on pair and sheet furnaces are practically the lowest. It is not always a question of how hot the bar or sheet may be but the

distribution of heat. An even heating is our chief object and this condition is not always attained due to the fact that the bars or sheet are stocked in the heating chamber thus often causing cold centers and hot edges which subsequently cause their uneven elongation under the rolls.

With an idea as to a few of the principal mechanical features of hot rolls let us follow an order through the mill noting the method of handling and the physical and microscopical changes that take place in its subsequent operations.

Breakdown of Bars

As previously mentioned the sheet bars are cut on the bar mill so that their length will be the width and their thickness equal to the length of the finished sheet. In other words we place the sheet bar crosswise into the rolls, thus rolling it in the opposite direction to which it was rolled on the bar mill. The bars come down from the bar mill piled on skids and are placed in front of the pair furnace. They are then charged in lots of 8 to 20 pair or 16 to 40 bars which constitute a heat, the number charged depending on the size sheet to be made and the number to be rolled at a time.

Once charged they must be carefully watched to see that they are uniformly heated. With the general run of sheet bar they will be heated to a temperature range of 12500-1450 deg. F. Care must be taken to keep up a constantly reducing atmosphere to prevent the raising of scale which in turn prohibits a clean smooth surface desired on automobile sheets. On charging, the bars are usually laid up next to the bridge wall and upon reaching the desired temperature are stacked in one or two piles near the front of the furnace for soaking until ready to be rolled.

This stacking leaves the rear of the furnace free for the next charging which is laid up in a similar manner. As hot bars in pairs are constantly and periodically demanded by the breakdown rolls only a limited time is allowed to heat and soak these bars which require constant watching to prevent over-heating and oxidizing. As the bars are needed they are removed in pairs, dragged to the front of the breakdown rolls and laid out on a plate known as a "fore plate". Here the loose scale, powdered coal, or dirt is quickly removed by brushing with a wet broom or steel brush. In the meantime the screws have been slacked off to allow for the passage of the bar between the rolls. The bar is then passed crosswise into the rolls by the feeder or rougher to the catcher on the opposite side of the mill. The catcher in turn grasps the bar with his tongs and by using a cross bar or billy roll fastened between the two housings elevates the bar and sends it back over the top roll to the rougher. At the same time this first bar is being returned, the rougher is feeding the second bar into the rolls. The screws, as operated by the large hand wheel or motor drive meanwhile are being set down to reduce the space between the rolls after each pass so that the sheet is gradually taking on length and decreasing in thickness.

After both bars have been given two to five single passes in this manner they are again laid on the fore plate, matched together and given several passes until they have been elongated to about one-half their specified length. In other words if we want the sheet to be 120 inches long and allowing 5 inches for end scrap which makes an overall length of 125 inches, we will elongate these matched sheets to 62 to 65 inches. Thus we have reheated and elongated in three to five single and two or three matched passes, two-sheet bar to about one-half their intended length on the breakdown rolls. If these

single and matched passes are more or less constant the temperature at which these bars are finished in breakdown form will vary between 800-1000 deg. F. depending on their initial furnace temperature and the amount of draft which they received. Fewer single and matched passes are necessary the hotter the steel and the greater the draft.

These breakdown sheets are then piled to cool on the delivery floor. As they represent a transition point in making a black sheet we would not be vitally interested in either their physical or microscopical properties.

After they have cooled they are sent either to the sheet furnaces where they are reheated for rolling to the specified size or pickled as a preliminary step toward the making of a full pickled, full finished automobile body sheet. This pickling allows the rejection at this point of any breakdown sheets which show surface defects such as scabs, seams, blisters, pinchers, etc., which would be rejected at a later point in its manufacture.

As a matter of interest let it be mentioned here that either the sheet bar or breakdown sheet may be the first pickling of a full finished sheet. Pickling the bar is less expensive, less defects are noticeable and more care must be taken in its heating in the breakdown furnace, while pickling the breakdown sheet is more costly but more defects can be noted as we have a greater area to pickle and surface to note.

Hot Mill Finishing

The breakdown sheets after cooling, and pickling, if any, are next carried to the sheet furnace where they are matched up as to size in piles of two, three or four sheets each which are designated as "packs". The 16 and 18 gage sheets are usually matched two sheets to a pack; 19, 20, 21 and 22 gage (depending on its size) are matched three sheets to a pack while 22 gage in small sizes are matched four sheets to a pack. The idea of matching up these breakdown sheets is to place in one pack sheets having as near the same area as possible thus making a uniform sized pack to roll. These matched packs are then placed in the sheet furnace and turned up against the bridge wall and sides of the furnace and heated to about 1300-1400 deg. F. They are then turned down upon the floor of the furnace and stacked for soaking similar to the stacking of pairs in a pair furnace.

More precautions must be taken in heating the breakdown packs than for sheet bar in pairs as we now are ready to roll the sheets to their final length. The packs must be uniformly heated, the finishing rolls must be in good shape and the draft regulated so as to pull the pack evenly through the rolls. Depending on the initial temperature of the pack and the draft on the rolls the pack may be given three to five passes to elongate it to its specified length plus a sufficient amount of end scrap.

The pack is pulled from the furnace to the fore plate of the finishing mill and the dirt, powdered coal or light scale is brushed from it. Before starting them through the roll, the rougher pulls the sheets apart with his tongs in order to loosen them should they have stuck together in heating as well as to straighten or match them up again.

The pack is then passed through the mill a number of times with the screw adjusted until the sheets have been elongated nearly to the specified length. At this point the pack is measured with a steel rod to determine its length which is the only means of knowing its gage. If it is a trifle short and another pass will elongate it too much and cause it to be light to gage the subsequent packs of the same size are given more draft in order to finish to the correct length in a certain number of passes.

The passing of a finishing pack back over the top of the rolls is somewhat different from the way sheet bar is passed back over the roughing rolls. At this point the sheets are long and bulky and it is therefore necessary that they be passed back over the top roll by means of a mechanical contrivance which helps the catcher to properly handle them.

Two straight iron "legs" about 40-50 inches apart (depending on the width of the rolls) and 6-8 feet long are elevated about a foot from the floor and suspended in the middle. As the sheets come through the rolls they move out along these legs and the catcher by bearing down on the end farthest from the rolls, elevates the legs and the end of the pack nearest the rolls and by a light push with his tongs starts the pack back over the top roll to the rougher.

Thus in two reheats and two independent stands of rolls we have elongated a sheet bar to the size sheet demanded. Such a sheet is called black sheet and as previously mentioned must be given further refining. The sheet is stiff and hard as the grains of iron have been critically strained as we will presently show. Before further refinement such as annealing, normalizing, pickling and cold rolling takes place the sheets are sheared to the size specified on the order on hot mill shears illustrated in Fig. 3.

As soon as the sheets have cooled to room temperature, the shearman and his helper pick up a pack at a time (which may be two, three or four sheets as rolled on the mill) and place on the casters in front of the shear which allows the bulky pack to be easily turned. The gage stops are set for the length and width specified and the excess metal and ragged edge of one side of the pack is removed thus straightening that side. The pack is then turned on its casters and the sheared side is held against a straight edge thus allowing a square trim for one end.

This process is then repeated in shearing the remaining side and end except that the side and end already sheared are held firmly against the gage stops on the table thus giving us the correct width and length with commercial tolerances.

From this point on the sheet goes through many processes of refinement depending on its use and the automobile part on which it is to be used, all of which must be described in separate articles.

Defects in Hot Rolling

A great many defects, very injurious to full finished automobile body sheets, originate in the hot mill. As most of these defects are of such a nature that subsequent treatment will not in all cases eliminate them, hot mill practice must be very carefully watched. Among the main defects encountered are pinchers, spreaders, floggers, heavy ends, grease marks, open surface and polishing scratches.

Before we enter upon a discussion of these defects we should understand the difference between a so-called full pack and an open pack. This primarily refers to the end of the breakdown sheets after being roughed down and are illustrated in Figs. 4 and 5, respectively. In a full pack (Fig. 4) the center of the sheet has been elongated more than the sides, thus leaving the end convex in shape. This may be caused by several factors principally when the rolls are slightly puffed in the center thereby causing more pressure or draft on that portion of the sheet. In a hollow pack, as in Fig. 5, the sides of the sheet have been elongated more than the center causing a "fish tail" end concave in shape. This also may

be caused by several factors, among which are (1) a hollow or concave mill and (2) an under-heated bar having hot sides and a cold center. Thus breakdown packs will vary in their end shape from convex to concave or full to hollow respectively and brings out another good reason for matching the finishing pack.

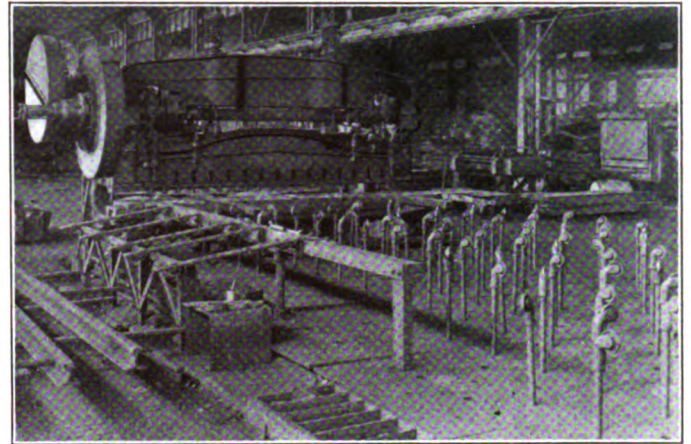


FIG. 3—Shear and casters.

With these shapes in mind we may run a full pack (Fig. 4) on a hollow or concave roll and cause "pinchers". Pinchers run in from the sides toward the center of the sheet in ridges which curve toward either the front or the tail end of the pack. They are also caused by an off and on gripping of the rolls running on dry bearings or poorly lubricated necks. Pinchers are also caused by improper heating of the breakdown sheets wherein the center of the pack is colder than the outside.

A full pack going through the rolls under an excessive pressure or draft causes "spreaders" or an uneven flowing of the metal and whose appearance is not unlike that of a pincher. In fact a spreader is the beginning of a

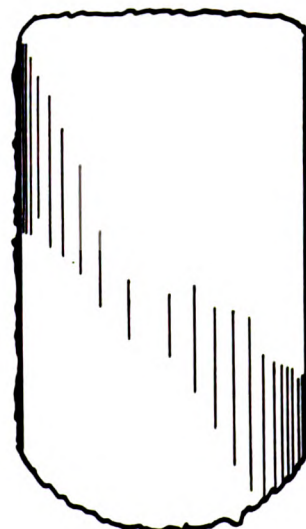


FIG. 4
Full pack.



FIG. 5
Hollow pack.

pincher and some mills make little or no distinction between these two defects. "Spreaders" are sometimes called "squeezers" and at times may be derived from a slight shifting of the sheets in the pack which has a tendency to push the semi-plastic steel into ridges which are not always eliminated in the hot rolling.

"Floppers" usually come from a hollow pack (Fig. 5), running through full or slightly convex rolls. This gives the middle of the pack more pressure which is already heavy in the middle and usually results in the tail end of the pack flopping as it enters the rolls and leaves ridges running from slightly concave to parallel in shape, on the end of the sheets.

"Heavy ends" are usually caused by sheets of the pack not being evenly matched or the shifting of sheets during rolling. This may cause the ends running out over to be heavy and those ends inside the pack to run thin. Heavy ends should be sheared off but often get by the shearmen. Heavy ends are a menace to good press work and will often cause uneven drawing of the sheet due to uneven tension under the holddown.

"Hot mill marks" come from dirt from furnaces and from the air, settling on the sheets or rolls. These defects are usually noticed and if objectionable the rolls are polished with a carborundum block. This polishing must be uniform across the rolls otherwise the sheets which follow may bear so-called "polishing scratches". These may be, possibly, eliminated after the sheet has been softened by annealing and then cold rolled. These scratches usually run the entire length of the sheet.

"Open surface" is usually pitted surface caused by the rolls being rough or the pack too hot, thereby causing a slight sticking of the sheet. "Grease marks" are very objectionable and come from a splashing of the grease from the bearings or necks onto the sheets or rolls. Rolled in grease marks are not usually removable and are classified as second sheets or "seconds" in surface quality.

Influence of Hot and Cold Work on Structure

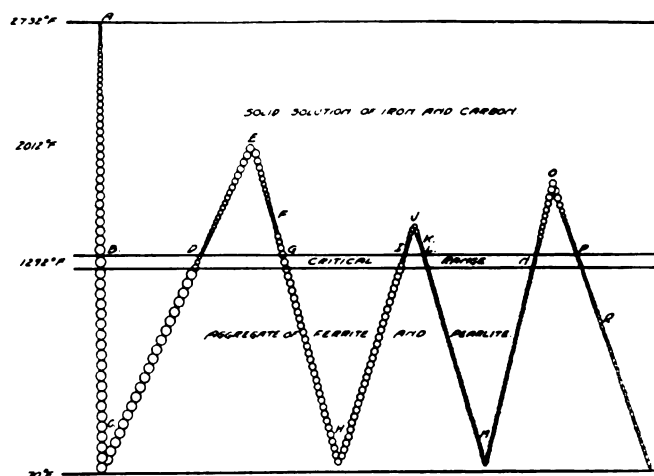
Before discussing the physical properties of a black hot finished sheet with its resulting grain structure, a better understanding of microphotographs showing these structures would be brought about by a general knowledge of the effect of hot and cold work on low carbon sheet steel. The fact that it usually takes two reheats (17 gage and lighter) to hot roll sheets to their size, brings into the discussion the fact that thermal as well as mechanical treatment contributes largely towards its physical formation.

It is already evident that in spite of these two reheats a considerable amount of rolling is necessary in order to reduce the bar to sheet form. In the lighter gages of sheet as used for automobile bodies, the increasing surface area of either the bar or breakdown sheet allows rapid dispersing of its heat resulting in the steel losing its plasticity very rapidly. Together with this fact the temperature of the steel must be held fairly low to prevent oxidation or scaling. These two factors contribute largely towards the reason for the second reheating in hot finishing sheets on the hot mills.

The hot working of sheet steel, as we shall interpret it, is the mechanical working, by drawing, pressing, rolling or hammering, while the steel carries a temperature which may range from its solidifying point to its critical range. On the other hand the cold working of sheet steel is mechanically working the steel by drawing, pressing, rolling or hammering, while the steel carries a temperature ranging from its critical range to room temperature. Therefore the distinguishing point between hot and cold working of sheet steel lies at its critical range which will be that point where the metal changes from a solid solution of iron and carbon (austenite) to an aggregate of ferrite and pearlite. Mechanically working the

steel while in a solid solution or above its critical range, results in a refinement of the crystals of iron. If the working stops at a point well above the critical range the steel cools undisturbed from that stopping point to the critical range with the result that the grains of iron enlarge or grow as undisturbed cooling promotes grain growth.

If, on the other hand, the steel is mechanically worked below the critical range while as an aggregate of ferrite and pearlite, the grains are distorted which remain deformed and with pronounced working are elongated in the direction of the working forces. This critical range for a .10 per cent carbon sheet steel is the A_1 point or approximately 700 deg. C. Thus if we heat our sheet bar or breakdown sheet above 700 deg. C. (1292 deg. F.) we are above the critical range and as it merges into this range it has a fine grain structure such as we would want in the final sheet. But at this temperature the sheet is



Graph I—Influence of hot and cold work on sheet steel.

not plastic enough for deformation so the bar or sheet must be carried to a higher temperature before mechanical working begins.

With these facts in mind let us look at Graph I where in the size of the circles denote an increase or decrease in size of the iron crystals. Take a hot ingot of sheet steel solidifying in the mold at the point A. If the ingot is allowed to cool undisturbed to room temperature the grains of iron will grow, as previously explained, until they reach the critical range at the point B. At the point B the iron in the mold changes from a solid solution to an aggregate and the size of the crystals will remain unchanged all the way down to room temperature at C, with a resulting coarse grained structure usually found in castings.

Let us now reheat our ingot in order to roll to sheet bar size. On the reheat, as the steel passes up through the critical range at (D), the crystals of iron merge from the aggregate back to the solid solution and therefore have a fine structure. In order to get the ingot hot enough to roll to bloom and sheet bar size we must go to a higher temperature such as at (E), and in doing so will cause crystallization with the grains proportionately the size indicated by the circle at (E). As the ingot is reduced in size by pressing or rolling the crystals are broken up into a much finer structure and remain thus or are even broken up finer by the persistent working. As long as the work continues the grains will have no chance to grow. However, let us suppose that the sheet bar was finished at about 1400 deg. or at a point called (F), and from this point on cooled slowly and undisturbed to the critical

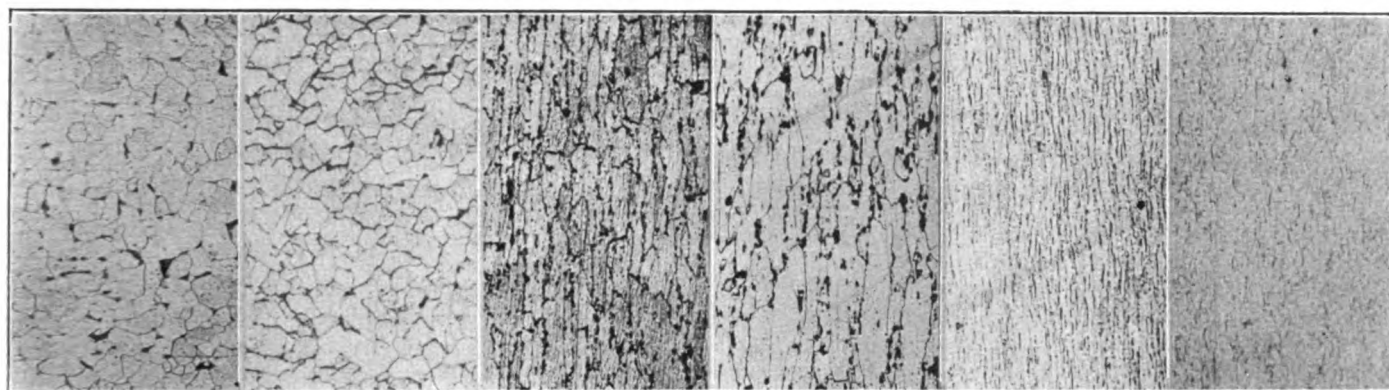


FIG. 6

FIG. 7

FIG. 8

FIG. 9

FIG. 10

FIG. 11

Structure of sheet steel, magnification 100X.

range (G) and then on to room temperature (H). The slow undisturbed cooling from (F) to (G) allowed grain growth with the result that there was a slight growth at (G) remaining unchanged to room temperature (H).

A microphotograph of such a steel is shown in Fig. 6. This is a .11 per cent carbon sheet bar whose mechanical working stopped approximately at a point 125-150 degs. F above its critical point. In this magnification of 100 diameters the grains have grown somewhat and are more or less equi-axed and showing no strains from their hot work.

The sheet bar is then reheated in the pair furnace from the temperature points of (H) to (I) and as it merges into the critical range and changes its allotropic form, the grains are again very fine but grow as the bar is heated to about 1400 deg. F or the point (J). Elongation of the bar then begins at (J) which breaks up the large grains and the rolling continues to a point (K) just above the critical range (L) where the maximum grain refinement by mechanical working is theoretically possible. The bar, now in the form of a breakdown sheet, is cooled slowly to room temperature (M) and a section magnified 100 times, in Fig. 7, is shown a very fine equi-axed structure which indicates that the rolling had stopped at a point where the maximum grain refinement had taken place and this point was so close to the critical range that there was no chance for grain growth. This Fig. 7 is also a .11 per cent carbon steel and as the steel changed from a solid solution the austenite grains changed into as many pearlite grains (dark areas) with the precipitation of free iron or ferrite (light areas).

Let us once more reheat the breakdown sheet (in pack form with one or more other sheets) to a temperature of about 1400-1500 deg F. (O) and elongate to the desired size on the hot finishing mill. This temperature is as high as we can commercially heat these sheets without scaling them and due to their large surface area cool very quickly with the result that our final pass or two for the correct size is when the sheet is well below its critical range or according to our earlier statements we are now cold rolling. As this rolling continues the steel passes through its critical range (P) and subsequent rolling begins to elongate the aggregate of ferrite and pearlite and forces the grains to move in the direction of rolling until work ceases at the point (R). Thus from a point slightly below the critical range (P to R) the sheets have been cold worked and, depending on the draft of the mills, certain "directional, preproperties" have set in.

The structure of sheets after this final rolling magnified 100 times appears as in Fig. 8 showing the elonga-

tion of the crystals in the direction of rolling. As a comparison Fig. 9 shows a sheet steel of .15 per cent carbon not so severely elongated as the steel in Fig. 8 or in other words there was very little work on the sheet after its temperature had dropped below the critical range.

Directional Properties of Black Sheet

"The "directional properties" previously mentioned can best be explained along with the physical properties of the finished black sheet. The fact that we have severely strained the crystals of iron more in one direction than in other will tend to influence the electric limit, tensile strength and especially the ductility. In other words these physical properties will vary very much in accordance with the direction of testing whether at right angles to the direction of final rolling or parallel to it.

Briefly, tests at right angles to the direction of rolling show a minimum elastic limit, tensile strength and ductility as expressed in the elongation of 2 in. and 8 in. test strips. Tests taken parallel to the direction of rolling show, in comparison, a higher elastic limit, tensile strength and ductility as expressed in the elongation of 2 in. and 8 in. test strips.

Thus Fig. 10 shows a longitudinal 100 magnification of a .095 per cent carbon steel as it came from the hot finishing mills. It can be readily noticed that the crystals have been severely distorted in the direction of rolling. Fig. 11 shows a transverse 100 magnification of the same steel and to summarize the properties of black sheet as well as the approximate differences in directional properties the following table is self-explanatory.

TABLE I—Comparison of Directional Properties on Hot Finished "Black Sheet."

Sample number	1	2
Micrograph number	10	11
Magnification	X-100	X-100
Direction of test to final rolling	Parallel	Transverse
Tensile strength (ultimate) in lbs. per sq. in.	62,400	57,600
Per cent elongation in 2 in. test strip	16.5 per cent	15 per cent
Per cent elongation in 8 in. test strip	10.8 per cent	8 per cent
Hardness (Brinell) 500 lb.	100	119
Hardness (Rockwell) "B" scale 1/16-in. ball 100 kg. weight	72	72
Ductility per Olsen testing machine (depth of draw in in.)	321 in.	324 in.
Ductility per Erichsen testing machine (Depth of draw in Mm.)	7.6 Mn.	7.8 Mn.

Stokers Applied to Annealing Furnaces

Annealing Furnace Stokers with Boiler Type Grates Effect Important Improvements in Annealing Practice—Fuel Saving Considerable—Temperature Control Easily Maintained

By J. B. WHITLOCK*

THE application of stokers to metallurgical furnaces is a step yet to be taken by a large number of manufacturers, yet a few companies have taken this step forward. Having realized by actual use, the fundamental advantages of mechanical over hand-firing, these companies seek to better the existing operation by a stoker of a design that has, inherently, such features as will more nearly approach the results ultimately desired.

We have at this plant a series of 12 new box-annealing furnaces arranged in six batteries. Prior to the building of these furnaces, a new stoker developed by the Westinghouse Company was tried out in one of the old furnaces in order to compare the results between this stoker and our old type of stoker which had been in use for some years. The Westinghouse stoker is essentially a single retort underfed type as used with steam boilers, but with such modifications as were necessary for application to this class of work.

The one main feature of the stoker, the unique motion of the grates, was not altered for it was this phase of the design that promised the results desired and which were, in practical operation, unobtainable with the old stokers which had stationary grates. Because of the latter fact the old stokers were necessarily narrow since the lack of motion restricted the limit to which the coal could be distributed sideways and properly burned. Therefore, two stokers per furnace

were required and this made it necessary to build them in dutch-ovens to secure a rugged furnace structure. The new stokers extend along the entire side of the furnace. This permitted of a design with one sprung arch. The manner in which the new furnaces are standing up proves the merit of this design.

Furnace Construction

The photograph of the interior of one of the furnaces is typical of the entire installation. They have all been in continuous operation since August 1927, and as yet no repairs to the brick walls and roof have been necessary, in fact, the refractory of the furnaces looks like new. This condition can be attributed to a good grade of refractory, good workmanship in the furnace erection, and a good flame condition in the furnace during the operation. This latter point is a very good one since it draws a distinct comparison between the old type of stoker installation against the new. In the old installation we had two small combustion chambers on the one side of the furnace whose entire opening did not equal the length of the charge to be annealed. This caused a much higher temperature to be concentrated in the small areas in order to drive the mass up to the required annealing temperature. This annealing temperature was much lower than the temperature we received in the two small combustion chambers. In order to maintain this greater temperature in the chambers, it was necessary to drive the stokers to the limit and as a result we received an intense, abrasive flame which caused considerable dam-

*Superintendent of Maintenance, American Rolling Mill Company, Zanesville, Ohio.

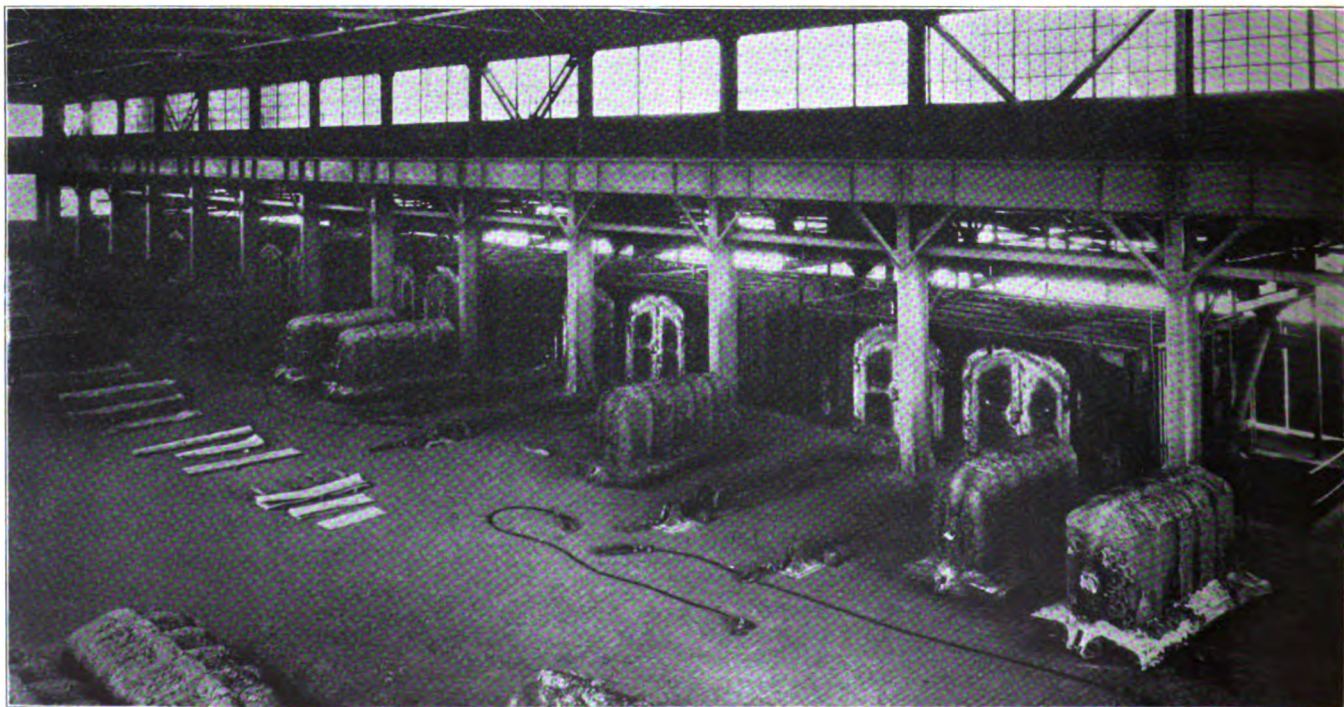


FIG. 1—Battery of annealing furnaces.

age to the brick-work. With the new installation we have an even blanket of flame over the entire mass to be annealed, which is not spotty or abrasive, and

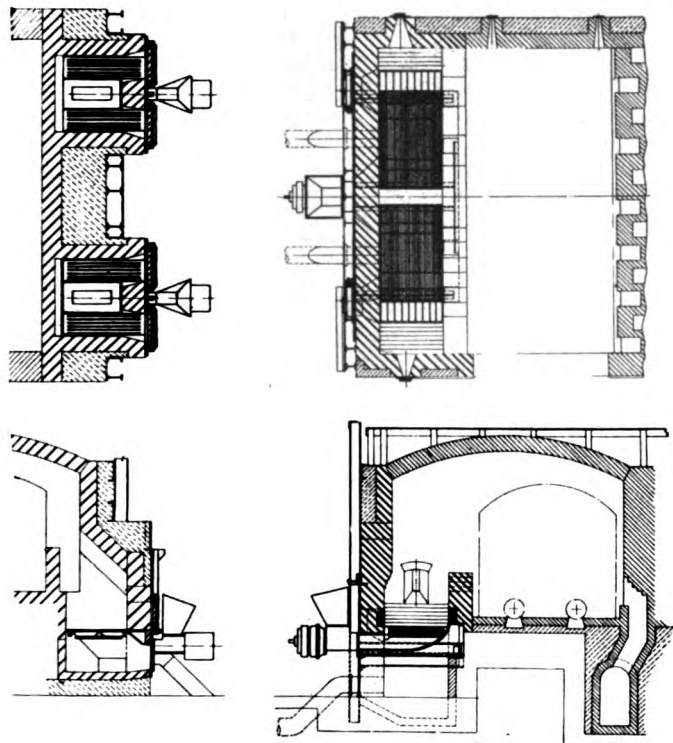


FIG. 2—Left—Old type stokers and dutch ovens. Right—Furnace with new type stokers.

which is approximately of the same temperature as the mass to be annealed. As a result our brick work is not being cut away by the flame action.

The next essential of a stoker to give uniform heating is that its fuel bed be flexible, that is, all sections under manual control. In these new stokers not only is the rate of coal fed to the retort adjustable, but also the rate at which the coal is spread laterally from the retort is controllable on either side independently. The distribution from the retort to the dump grate is positive, consisting of a number of oscillating steps which

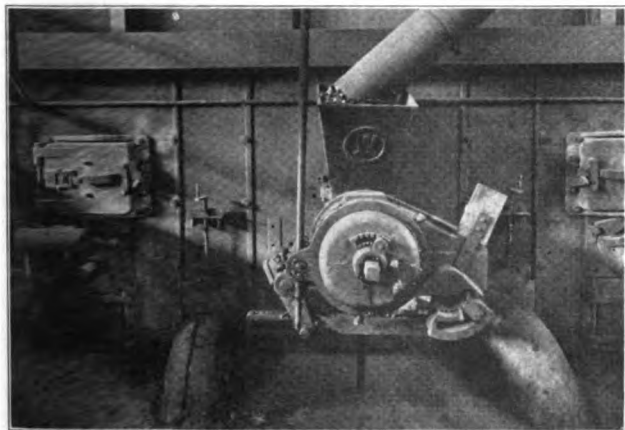


FIG. 3—View of stoker.

move the coal progressively across the grate. This action agitates the fuel, permits thorough and uniform air distribution, and results in excellent combustion. The main coal feeding mechanism is a screw which

may be of various pitches depending upon the maximum amount of coal required within a practical speed range.

An interesting development on these furnaces that brought out the flexibility of fuel bed control in a striking manner is the stepped bridgewall. When the furnaces were first built the bridgewall was of a uniform height throughout as in the older furnaces. It had always been difficult to hold anywhere near equal temperatures front and back because of the considerable air infiltration around the main furnace doors. It was found that with the new stokers the combustion on either side, corresponding to either end of the furnace, could be compensated for by proper adjustment of the grate motion. Obviously, therefore, the combustion could in like manner be held uniform clear across the stoker regardless of fuel variations or other influencing factors. Hence, a bridgewall of increasing height from front to rear would, with a uniform fuel bed, compensate for air infiltration at one end and produce a uniform temperature.

The chart here reproduced represents a typical cycle for any one furnace, consisting of coming-up heat, holding and cooling preparatory to recharging. A thermo-couple at each end of the furnace connects

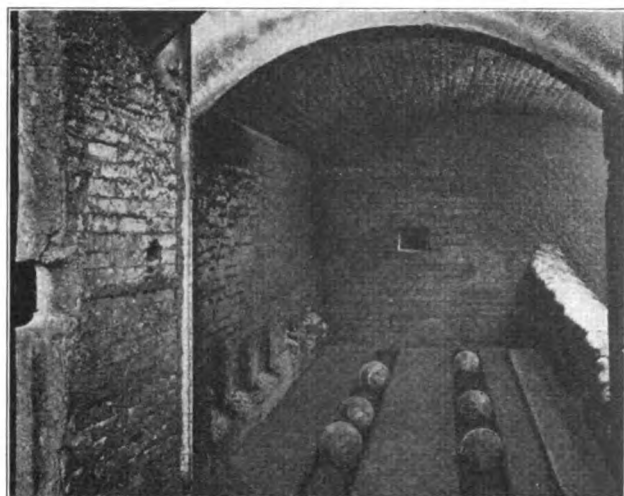


FIG. 4—View of inside of furnace showing bridge wall.

with the same pen in the temperature recorder. At regular short intervals the recording is automatically transferred from one thermo-couple to the other. Note that at the beginning of the cycle the temperatures at the respective ends are materially different and that they approach each other as they near the holding temperature. The important thing is that they are practically identical during the holding and soaking part of the cycle.

No appreciable cooling of the furnace occurs when the fires are cleaned because it is only necessary to drop the dump grates. They are steam operated and therefore the cleaning is accomplished even a little faster than with hand operated grates.

The furnace cycle with these stokers can be speeded up considerably, due to the fact that the agitating grates and uniform air distribution permit a higher rate of combustion per square foot of grate surface.

Fuel Economy

The gases of combustion are very satisfactory. Samples at the ends of the furnaces show the average analyses given on next page.

In addition to all the advantages already given, the new stokers not only burn a wider range of coals suc-

cessfully, but effect a considerable coal saving amounting to about 20 per cent. The combustible in the refuse has been reduced from 30 to 12 per cent. It is interesting that a great deal of the refuse from the old stokers is burned on the multiple retort stokers in the boilerhouse. It is expected that a greater net coal economy will result when the operators become more proficient in handling the stokers to produce the desired furnace conditions.

		CO ₂	O	CO
Coming-up	{ Front	15.3	3.6	...
	{ Rear	14.5	4.8	...
Holding	{ Front	13.9	5.7	...
	{ Rear	12.1	6.4	...

The air pressures (inches of water) in the stoker windbox are as follows:

	Avg.	Max.	Min.
Coming-up	0.65	0.77	0.51
Holding	0.20	0.30	0.10

In conclusion, we can say that to date the stoker maintenance due to regular service has been nothing. Several changes were made in some of the mechanism, but these were in the line of development rather than replacements due to service.

The Manufacture of Alloy Steel

(Continued from page 765)

Coupled with the special requirements the characteristics of the various alloys, such as nickel for stress distribution and ability to mould while hard, as against chromium to localize stress, and the problem becomes complicated. Vanadium may be used to insure the carbonizing of a thin section, or it may be used to protect a very thin part of an otherwise heavy forging, as in locomotive work. Molybdenum may be added to develop certain cutting qualities at high hardness or used to provide a very low critical temperature at which volume change takes place. The alloys are tools used alone or in combinations to produce specific results.

The skill of the maker is more important in the present stage of knowledge of the art than the quantitative chemistry. This means that alloy steels are really produced under routines, as were the old brand-named products. Engineering standards are gradually providing guides to replace the brands of old, but many years must elapse before technical knowledge will be competent to insure the producer of alloy steels that his product can be produced to specifications. The product shipped by the present generation will largely go forward as a means of the combined ability of the individuals who contributed a part of their art to the whole.

The manufacture of alloy steels is on an economic plane to bear the pressure of costly research work. The laboratory facilities provided are usually the finest found in steel manufacturing. The men employed are usually selected for their peculiar ability to handle certain problems. With all the technical assistance possible the manufacture of alloy steels remains distinctly an art and as such will continue as long as the user can detect superiority of product that he cannot define in terms of engineering standards.

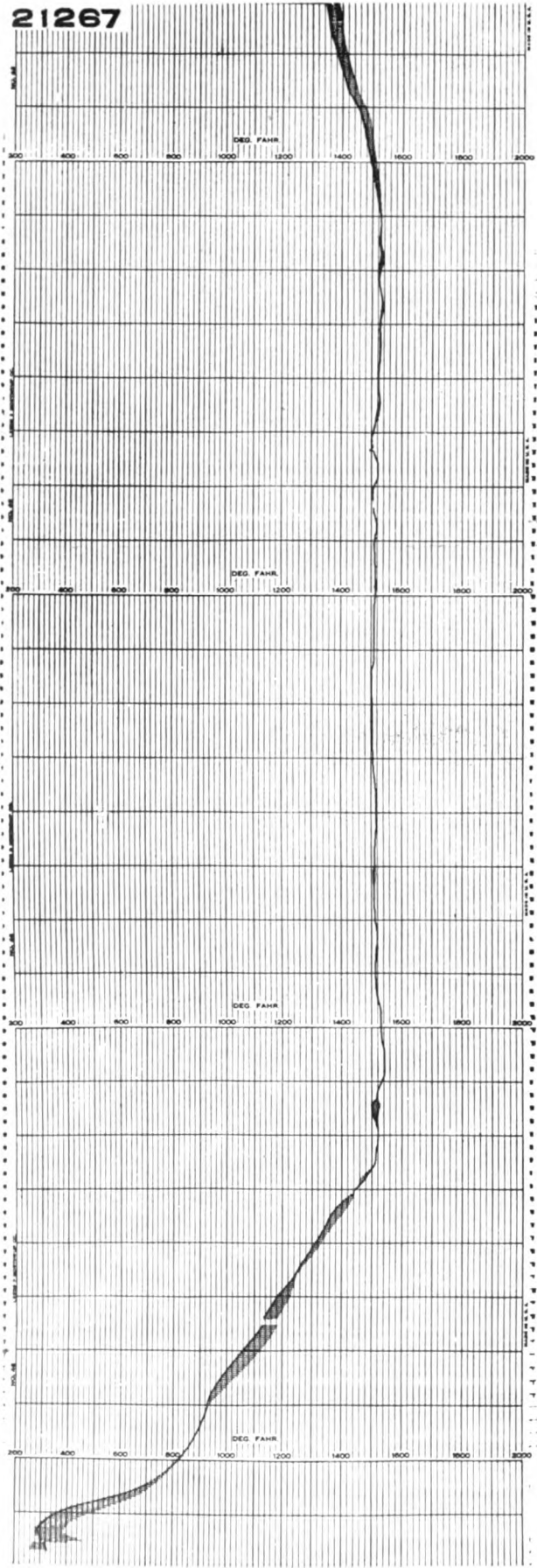


FIG. 5—Chart of temperature cycle.

TENTATIVE PROGRAM

Twenty-fourth Annual Convention

— AND —

Iron and Steel Exposition

Hotel Stevens
Chicago, Ill.

June 25th to 29th
— 1928 —

MONDAY, JUNE 25TH

9:00 A. M.

Registration

(Foyer at Exposition Entrance)

James L. Mills, Chairman

10:00 A. M.

Business Session

A. J. Standing, Chairman

A. G. Place, Secretary

10:20 A. M.

"Report of Electric Heat Committee," by Geo. H. Schaeffer, Chairman.

11:20 A. M.

"Report of Electrical Development Committee," by W. H. Burr, Chairman.

11:40 A. M.

"Report of Electric Welding Committee," by A. G. Place, Chairman.

12:00 Noon

"Report of Standardization Committee," by A. C. Cummins, Chairman.

1:00 P. M.

"A. I. & S. F. E. Luncheon," auspices of Safety Engineering Division, C. L. Baker, Chairman.

1:30 P. M.

"Official Opening of Iron and Steel Exposition."

2:00 P. M.

Technical Session

"Methods and Systems Used in High Tension Practices in Modern Plants," by Eugene Vinet, Assistant to Vice President, Middle West Utilities Company, Chicago, Ill.

Discussion on above subject by:

F. O. Schnure, Bethlehem Steel Company, Sparrows Point, Md.

R. M. Hussey, Jones & Laughlin Steel Company, Woodlawn, Pa.

9:00 P. M.

"Informal Reception in Ball Room of Stevens Hotel," Chairman, C. J. Smith, Illinois Steel Company, South Chicago, Ill.

TUESDAY, JUNE 26TH

10:00 A. M.

Technical Sessions

"Present Practices in Connection with Motor Driven Rollers," by J. C. Dobelbower, Engineer, Crocker Wheeler Electric Mfg. Company, Ampere, N. J.

"The Selection of Motors for Main Drives of Strip and Skelp Mills," by A. F. Kenyon, Engineer, Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

"The Selection of Motors for Main Drives of Merchant, Bar and Rod Mills," by C. B. Huston, Engineer, General Electric Company, Schenectady, New York.

WEDNESDAY, JUNE 27TH

Technical Session

"Fuel Savings Conference,"

J. C. McElhinney, Chairman

10:00 A. M.

"Insulation of Open Hearth Checkers," by L. B. MacMillan, Johns Manville Corporation, New York, N. Y.

"Boiler Pressures Above 350 Pounds," by J. B. Crane, Engineer, Ladd Water Tube Boiler Division of International Combustion Engineering Company, New York, N. Y.

2:00 P. M.

"Factors Governing the Purchase of Coal," by Morgan B. Smith, Engineer of Purchases, General Motors Corporation, Detroit, Mich.

"Instruments in the Iron and Steel Industry," by E. C. Eagles, Engineer, The Bristol Company, Philadelphia, Pa.

THURSDAY, JUNE 28TH

9:30 A. M.

Barton R. Shover, Chairman

"Anti-Friction Bearings for Roll Necks," by J. H. Van Campen, Chief Engineer, E. W. Bliss Company, Salem, Ohio.

"Anti-Friction Bearings for Motors," by J. C. Murray, Follansbee Brothers Company, Follansbee, W. Va.

"Anti-Friction Bearings for Auxiliaries," by E. S. Jeffries, Steel Company of Canada, Toronto, Canada.

2:00 P. M.

"Discussion of the Elements Entering Into the Cost of Producing Power," by W. B. Skinkle, Engineer, Pittsburgh District Power Committee, Subsidiary Companies of United States Steel Corporation.

7:00 P. M.

"Annual Formal Reception,"

J. J. Booth, Chairman, Gary Tube Company, Gary, Ind.

FRIDAY, JUNE 29TH

"Inspection Trip"

Final Announcement Later

Exposition Hours

9:00 A. M. to 5:00 P. M. Each Day

The POWER PLANT

Steel Plant Boiler Firing Flexible

Five Boilers Arranged to Burn Either Powdered Coal or Blast
Furnace Gas—One Boiler Equipped with Chain Grate
Stoker on which Coke Breeze Is Burned

By CHARLES LONGENECKER

A POWER plant that has fulfilled its mission most creditably is that at the plant of the Central Alloy Steel Corporation. This power plant, which now has been in operation for some years, was one of the first to burn in the same furnace either powdered coal or blast furnace gas. It was also among

The steam is utilized for the production of power for driving the mills and air for blowing the blast furnaces. Conversion is accomplished through one 10,000 kw. turbo-generator and two turbo-blowers with a capacity of 50,000 cu. ft. per minute.

Boiler House

In a building nearby the blast furnace are the six B. & W. 890 hp. Stirling type boilers placed as shown in Fig. 3. These boilers are equipped with both economizers and superheaters of such a size that steam can be supplied at a pressure of 300 lbs. and with a superheat of 150 deg. F. Feed water pumps supply the economizers with water at a temperature of 205 deg. F. so that before entering the boilers the water is heated sufficiently to raise its temperature 125 deg. F. to 150 deg. F.

Coal Firing

A glance at Fig. 3 will show that the arrangement of pulverizers and burners is rather unique. Thus, there are two pulverizers driven by steam turbines, and six by motors. On the two steam driven machines the coal feeder is actuated by a belt which is driven from a shaft, while the coal feeder on the six motor driven machines is operated by an individual motor. From each turbine driven pulverizer, coal is supplied to either of two boilers through two burners placed on each furnace. With this arrangement it is possible to burn coal in any two of the four boilers in case no current is received for the operation of the motor driven units. By means of a butterfly damper coal can be delivered to either one of the two boilers served by a turbine driven pulverizer.

The coal burned is an Ohio slack of high volatile, powdered to a fineness averaging 26.5 per cent on the 100 and 59.25 per cent on the 200 mesh screen. From the car the slack coal passes through a hopper, a crusher and onto a conveyor equipped with a magnetic pulley. If the coal is fine the crusher is not used. When discharged from the conveyor it is picked up by a bucket carried by a crane and is elevated and deposited into a 650-ton bunker is connected above the boiler furnaces. This bunker is connected by chutes to the small feed hoppers on the pulverizers and from these feed into the pulverizing chamber. In this chamber the coal is disintegrated by its impact against the beaters and grinding blades carried on the shaft of machine. It is then, in powdered form, discharged by means of fan blades, attached to the same shaft as

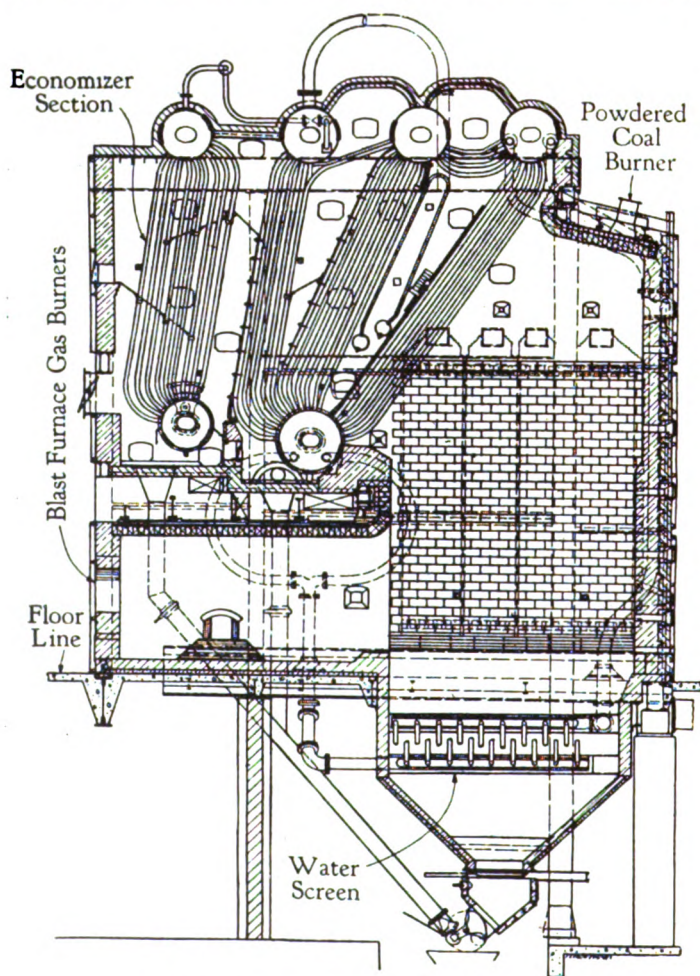


FIG. 1—Cross sectional view of boilers.

the first to give extensive application to the unit type of coal pulverizing machine for firing batteries of boilers. Still another feature to be found here, unusual to most plants, is the use of a tubular heat exchanger by means of which the blast furnace gas burned in the boilers and stoves is heated and dried.

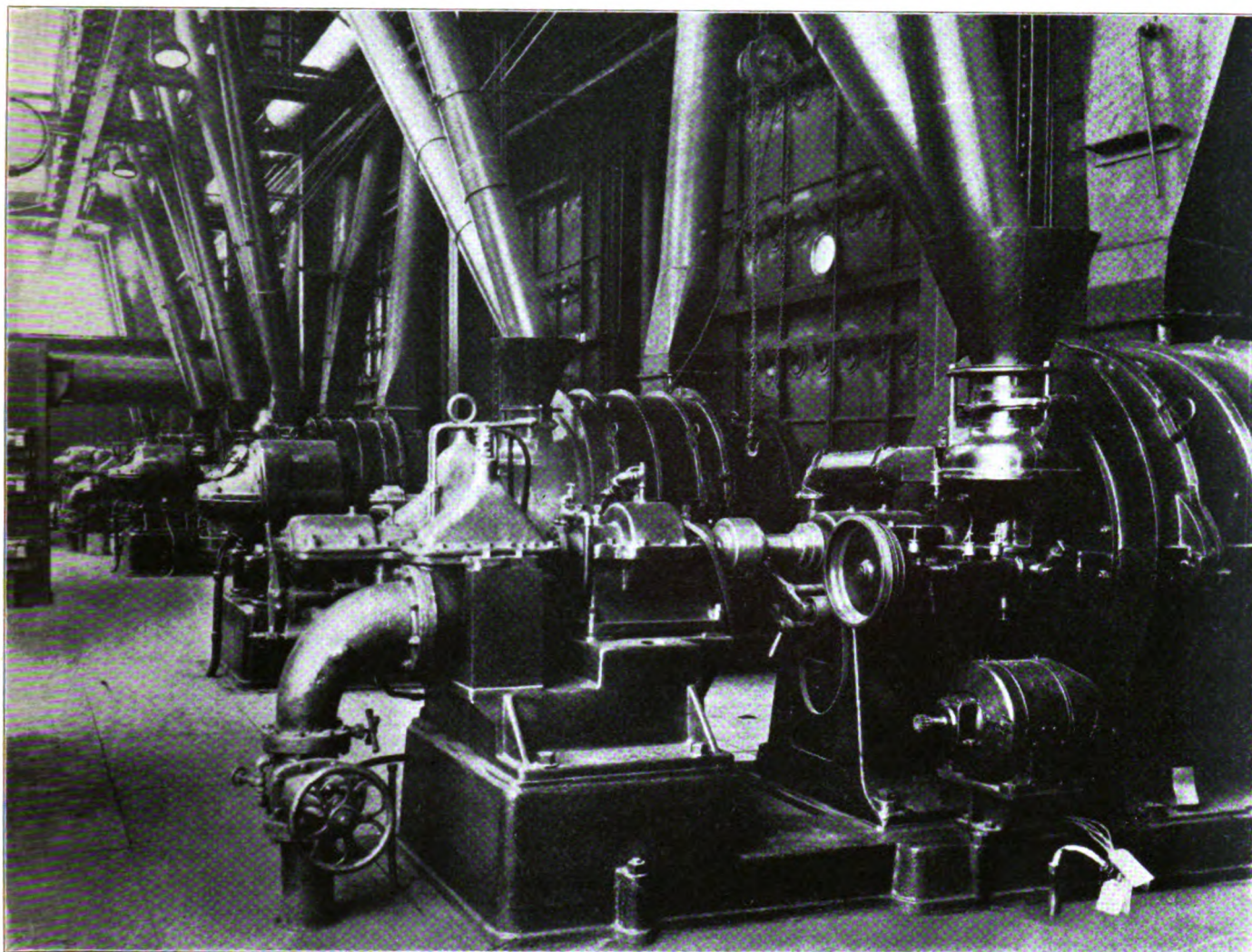


FIG. 2—Coal pulverizers with coal connections and drives.

the beaters, into the pipe leading to the burners. Each pulverizer has a capacity of 4,500 lbs. of coal per hour when the coal contains less than 5 per cent of moisture. The pulverizers are driven by 75 hp. motors and 75 hp. geared turbines. Fig. 2 shows the pulverizers and connections.

Tests taken on the powdered coal fired boilers are recorded in Table I.

Each boiler is equipped with four burners so placed that the stream of coal and air passes downward and parallel to the front wall. The flame then passes over the water screen and upwards and into the boiler proper as is evident from the cross sectional view as shown in Fig. 1.

Air for burning the coal is supplied from two sources. A portion is drawn through openings in the side walls and in passing through the walls is heated to about 300 deg. This air then flows through the pulverizing chambers and in doing so absorbs moisture to such an extent that the percentage in the coal is reduced about 50 per cent. A small quantity of air also passes in through coal feeder opening. It is necessary that a very considerable quantity of air be available to further combustion as the mixture of coal and air passes down through the combustion chamber. This air is admitted through parts in the front wall so spaced that the correct proportion is attained as the

flame progresses. Control of the inflow of air is accomplished either automatically or by hand. Electrical devices functioning through a motor connected to the stack damper make possible the maintenance of a constant pressure of .03 in. in the furnace chamber.

Blast Furnace Gas

At the rear of five of the boilers two gas burners have been installed consequently any of these boilers may be fired with gas, but since the one blast furnace cannot supply enough gas to fire all the boilers powdered coal must be burned in those not burning gas.

The heat inter-changer, through which the gas flows on its way from the wet washer to the boilers and stoves, is located at the base of the stack into which pass the hot spent gases from the blast furnace stoves. These hot gases pass through the inter-changer horizontally while the blast furnace gas passes vertically from top to bottom. The interval of contact between the gases although short allows for a flow of heat sufficient to raise the temperature of the blast furnace gas 30 to 35 deg. This increase in temperature not only increases the sensible heat in the gas, but causes its moisture to be vaporized with the consequent riddance of the deposition of sludge and scale in the burner and on the boiler tubes. Periodically the tubes of the interchanger are flushed. The tubes, 434 in number, are 4 in. in diameter and 12 ft.

TABLE I—Tests on No. 6 Boiler, Furnace Division, Massillon Works.

Stirling water tube boilers, with integral economizers, 8,900 sq. ft. heating surface, 4,460 sq. ft. economizer surface, 760 sq. ft. superheating surface. Fuel—coal, run-of mine, pulverized.

	Test 1	Test 2	Test 3	Test 6
Duration, in hours.....	9.9	9.85	4.416	4.067
Averages				
Steam pressure, gauge, corrected.....	280	286	265	290
Steam temperature	562	590	592	568
Temperature water entering economizer.....	204	205	205	199
Temperature water leaving economizer.....	280.6	296	302	296
Temperature gas leaving boiler.....	578.5	615	680	692
Temperature gas leaving economizer.....	346	409	428	327
Temperature gas at stack.....	335	344.6	372	348
Temperature boiler room.....	91.5	77.5	76.3	87
Temperature preheated air.....	334.3	356	330	.....
Temperature outside air.....	60.5	27.4	23.3	.....
Draft in furnace, in inches of water.....	.189	.21	.313	.192
Draft at damper, in inches of water.....	.291	.716	1.19	1.127
Draft between boiler and economizer, in inches of water.....	.....	.475	.85	.5
Draft drop through boiler and economizer, in inches of water.....	.102	.506	.877	.935
Quality of Steam				
Superheated, deg. F.	146	172	181	149
Total Quantities				
Total weight coal weighed, lbs.	44000	66000	34000	33600
Per cent moisture in coal as weighed.....	6.05	6.05	7.55	6.00
Per cent moisture in coal as fired.....	2.10	2.40	2.50	2.75
Total weight dry coal fired, lbs.	41400	62100	31430	31600
Per cent ash in coal.....	10.55	11.28	11.8	11.48
Total weight water fed to boiler, lbs.	416000	629000	308000	319000
Factor of evaporation.....	1.15	1.168	1.166	1.158
Total equivalent evaporation, from and at 212 deg. F.	478400	734000	349600	369000
Hourly Rates and Quantities				
Dry coal per hour, lbs.	4180	6370	7120	7750
Actual water evaporated.....	42100	63900	60750	78400
Equivalent evaporation per hour, from and at 212 deg. F.	48500	74500	81400	90700
Capacity				
Boiler horsepower developed.....	1404	2160	2358	2627
Rated horsepower	890	890	890	890
Per cent rating developed.....	158	243	265	295
Economy				
Water evaporated per pound coal weighed.....	9.47	9.52	9.07	9.5
Water evaporated per pound dry coal.....	10.03	10.1	9.8	10.1
Equivalent evaporation per pound coal weighed.....	11.1	10.85	10.57	11.0
Equivalent evaporation per pound dry coal.....	11.6	11.7	11.4	11.7
Efficiency				
Calorific value of 1 lb. coal as fired.....	12434	12564	12510	12608
Calorific value of 1 lb. dry coal.....	12700	12850	12830	12960
Overall efficiency	88.7	88.3	86.2	87.7
Analysis Dry Flue Gas by Volume				
CO ₂	15.05	14.13	12.43	14.5
O ₂	3.64	4.39	6.23	4.09
CO .....	.....	.067	.075	.018
N ₂ (by difference).....	81.31	81.413	81.265	81.392

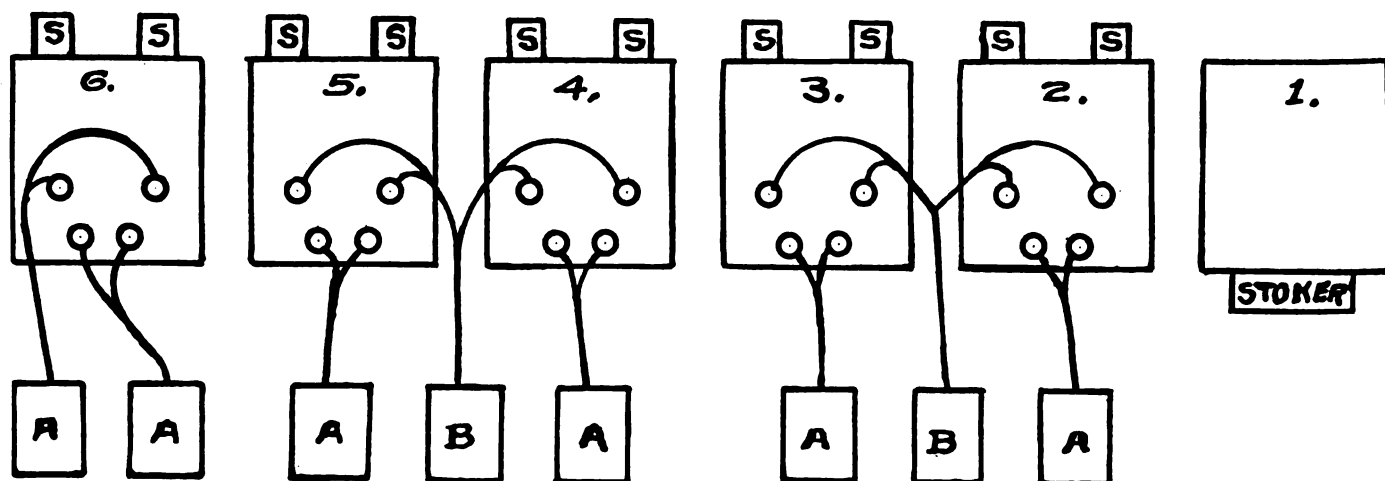


FIG. 3—Arrangement of boilers and powdered coal burners.

A—Motor driven pulverizers.

B—Steam driven pulverizers.

S—Steinbart gas burners.

LIST OF EQUIPMENT	
Boilers	Babcock & Wilcox
Superheaters	Babcock & Wilcox
Water Screens	Erie City Iron Works
Gas Burners	American Heat Economy Bureau
Powdered Coal Burners.....	Erie City Iron Works
Coal Pulverizers	Erie City Iron Works
Motor Drives for Pulverizers.....	General Electric
Turbine Drives for Pulverizers.....	Westinghouse Electric & Mfg. Company
Chain Grate Stoker.....	Riley Stoker Company
Fan for Stoker.....	Buffalo Forge Company
Fans for Gas Burners.....	Buffalo Forge Company
Ash Hoppers and Gates.....	Beaumont Manufacturing Company
Coal Handling and Crushing.....	Link Belt Company

TABLE II—Tests on No. 6 Boiler, Furnace Division, Massillon Works.

Stirling water tube boiler, with integral economizers, 8,900 sq. ft. heating surface, 760 sq. ft. superheating surface, 4,460 sq. ft. economizer surface. Fuel—blast furnace gas, wet washed, reheated in heat interchanger.

	Test 1	Test 2	Test 3	Test 4
Duration, hours	3.367	3.2	1.65	2.567
Averages				
Steam pressure (gauge).....	279	282	281	284
Steam temperature	592	590	572	603
Temperature water entering economizer.....	192	202	204	203
Temperature water leaving economizer.....	366	367	340	.....
Temperature gas leaving boiler.....	703	685	588	730
Temperature gas leaving economizer.....	460	449	377	463
Temperature gas at stack.....	362	277	322	.....
Temperature in boiler room	85.5	82	80.2	71
Temperature preheated air.....	167.3	183	182	159
Temperature blast furnace gas.....	94.3	98.7	92	76.3
Draft in furnace.....	.116	.17	.17	.....
Draft at damper.....	1.57	1.4	.4	1.15
Draft between boiler and economizer.....	.85	.57	.25	.....
Draft drop through boiler and economizer.....	1.454	1.23	.23	.....
Gas pressure in main, inches.....	9.5	22.3	21.0	14.4
Quality of Steam				
Superheated, deg. F.	176	174	156	186
Total Quantities				
Total weight of water evaporated, lbs.	162000	145000	50000	130000
Factor of evaporation.....	1.178	1.17	1.158	1.174
Total equivalent evaporation from and at 212 deg. F., lbs.	191000	169500	58000	152700
Hourly Rates and Quantities				
Actual water evaporated per hour, lbs.	48100	45250	30300	50650
Equivalent evaporation per hour.....	56700	53000	35200	59600
Capacity				
B.H.P. developed	1644	1535	1020	1730
Rated B.H.P.	890	890	890	890
Per cent rating developed.....	184.7	172.5	114.6	194.5
Analysis Dry Flue Gas by Volume				
CO ₂	21.18	19.88	20.6	23.65
O ₂	4.85	5.61	4.8	2.52
CO	.07	.....	.....	.....
N ₂ (by difference).....	73.9	74.51	74.6	73.83
Average Analysis of Blast Furnace Gas				
CO ₂	15.4	15.4	15.4	15.4
O ₂ .....	.....	.....	.....	.....
CO	25.8	25.8	25.8	25.8
N ₂	1.57	1.57	1.57	1.57
N ₂ (by difference).....	57.23	57.23	57.23	57.23
Loss due to moisture in gas.....	.5	.49	.47	.52
Loss due to burning hydrogen.....	1.05	1.05	1.02	1.05
Loss in dry stack gases.....	16.47	17.1	13.4	15.5
Loss due to incomplete combustion.....	.5	.....	.....	.....
Loss due to moisture in air.....	.2	.2	.2	.2
Loss due to radiation.....	3	3	3	3
Total losses	21.72	21.84	18.09	20.27
Per cent of heat to steam (efficiency).....	78.28	78.16	81.91	79.73

Note—Test 4 run with secondary air and ash pit plastered up.

1½ in. long thus giving 5,450 sq. ft. of surface for the contact of the two gases.
Two fans with individual capacities of 60,000 cu.

ft. of air per minute deliver preheated air to the burners. The two burners on each furnace burn
(Continued on page 793)

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Burning Coal on Underfeed Stokers*

Chemical and Mechanical Features Involved in Combustion
as Attained in the Underfeed Stoker Is
Herein Aably Discussed

By J. G. WORKER†

THE burning of coal on stokers is a combination of chemical and mechanical processes—chemical in so far as it involves the decomposition and disintegration of the coal and the recombination of its elements with oxygen, and mechanical with respect to the feeding of the coal into the furnace and the rejection of the incombustible residue.



J. G. WORKER

Bearing in mind this dual feature of the combined process, let us consider first the purely chemical aspects of the matter. The principal factors controlling combustion of solid fuel, so far as the chemist is concerned are the following:

1—Oxygen concentration.

2—Heat in the oxidizing zone, getting heat to the solid surfaces.

3—Lowering the concentration of CO_2 and water vapor at the point of oxidizing action.

4—Removal of gases of decomposition and mixing them with heated oxygen.

5—Removal of gas films on surfaces, by air velocity or turbulence.

6—Reactivity or combustibility characteristic of the solid surface.

1—Oxygen concentration, of course, means an ample supply of air from which the oxygen is secured.

2—Heat in the oxidizing zone means a temperature sufficiently high to permit easy oxidation.

3—Lowering the concentration of CO_2 and water vapor at the point of oxidizing action is a little more complex. In a concentrated CO_2 and water vapor atmosphere, there exists a combustion insulation and this atmosphere must be removed by scavenging.

4—Removal of gases of decomposition and mixing them with heated oxygen. This means that on decomposition, the so-called volatile gases are liberated and must be mixed with oxygen (or air), with which they must unite, and the whole must be heated to be burned.

5—Removal of gas films on surfaces by air velocity or turbulence. This means that the gas films, either combustible or otherwise, which cling or lie close to the surface of the solid fuel, also set up combustion insulation. This film must be swept away by correctly directed and high velocity activity, which will scrub these surfaces clean.

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6—Reactivity or combustibility characteristic of the solid surface. This means that different fuels have different characteristics of burning; that is what is commonly known as free or slow burning characteristics.

However we may burn coal, the same fundamental principles apply. A lump of coal on a grate is not a bit different from a smaller bit in the form of a particle suspended in air, except in the matter of size.

Coal in its early decomposition by heat forms a char or partly coked residue, which has a high coefficient of combustibility. It has been found that semi-coke—varying with the conditions under which made—are of a high order of combustibility. The porosity also of this intermediate solid residue, formed in the fuel bed, promotes its combustibility, as compared to the more compact raw coal.

Time Factor of Combustion

Now, for the carrying through of combustion, even of a very fine particle, to completion, the element of time constitutes a factor of much importance. A solid, even as powder, contains in each of its particles an immense number of molecules. It is a popular fallacy to think that even though a piece of coal is very small, its size speeds up the combustion with the molecular group that is necessary for combustion. For example, in a fine grade of commercial pulverized coal, the particle size distribution has been measured, and about 25 per cent found to be less than 25 microns (.025 millimeter = .001 in.) in diameter. In other words, if we had a screen with an opening of 1/1,000 of an inch—say a 600 mesh screen—about 1/4 of this powdered coal would pass through. These particles are extremely small, and in fact they grade down to 1/100 of that size, in powdered coal. But even one of these minute particles, when compared to one of its molecules, is, in all probability, about as our largest dirigible air-ship would be to a grain of wheat,—100,000 times its diameter. On the basis of certain radiographic, diffraction measurements of more or less crystalline substances an approximate indication of molecular dimensions has been obtained leading to the belief that the molecules of some substances may be of the order of 10 to the — 6th or — 7th power of a millimeter, or 1/1,000 to 1/10,000 of a micron, in diameter. A coal particle of say 10 microns (.01 m/m.) would, on assumption of any such molecular dimension, contain 10 to the 12th power or 10 to the 15th power molecules, say 1 million-million of them. This is highly speculative theory but it illustrates the order of molecular magnitude and the vast number of molecules that must enter into chemical union individually, in the combustion reaction.

These molecules, in order to combine with oxygen quickly, must be heated to the requisite temperature. And both those of the solid and the surrounding air and gases have a certain heat capacity.

If we blow into a lamp flame a well dispersed cloud of 200 mesh coal powder and blow it gently over the hot upper zone of the flame, the cloud inflames readily. On

the other hand, a quick violent puff of the same powder through the flame, without good dispersion, permits only very slight combustion, if any. A certain time of contact, in other words, is necessary to bring the particles into ignition. After ignition the propagation of flame through a cloud of suspended particles may be extremely rapid.

This is brought out here merely to illustrate the fact that combustion of a solid—whether of a lump or a particle,—is a conversion of molecules at its surface into gaseous molecules of its compound with oxygen, and this surface reaction requires heat to make it go rapidly, to bring it to a reaction rate such that its own heat, as produced, will support it. Rapid combustion requires oxygen concentration also, and a sweeping away of the products of combustion from the surfaces. This means, when the fuel is suspended in the form of fine particles, ample surrounding space, and turbulence. When it is burned on an underfeed stoker the oxygen concentration and the scrubbing away of inert gases from the surfaces of the combustible are accomplished by the multitudinous streams of air that sweep through the porous fuel bed.

Trace the course of the air through an underfeed stoker unit of the Taylor type, as shown in the accompanying cut (Fig. 1).

At the bottom, air enters charged with heat recovered from the flue gases. Automatic dampers regulate the flow of air to supply just the right amount to each small unit area of the grate.

Then the hot air strikes a layer of green coal, dries it and sweeps upward to ignite the volatiles in the coking zone.

Mingled with the air, these gases are driven through

the zone where the coked coal is burning. Every lump of fuel acts as a baffle to break up air and gas strata and mix them as they twist and turn through a labyrinth of passages. As a result of this scrubbing action fresh fuel surfaces are exposed continually to direct contact with the oxygen in the air.

Above the fuel bed, combustion is concluded with a minimum of excess air in a chamber whose walls contain heat-absorbing units that form an extension of the boiler.

Passing through the boiler, the air and gases travel through a preheater that traps heat which otherwise would be lost. Finally, the gases are discharged through the stack, smokeless and ash-free.

Mechanical Operations in Combustion

Turning, now, from the chemical to the mechanical aspect of the fuel burning problem, we find that there are 10 important functions that must be performed in the operation of mechanical stokers. They are the following:

1—A uniform and positive supply of the fuel to the stoker, with the rate of feed variable at will.

2—A feed of fuel into the stoker of relatively small quantities at a time, a wide range of speed in the rate of feed; a positive and correct distribution of the fuel in the stoker to replenish the fuel constantly wasted in the process of combustion.

3—Provision for feeding and ultimately discharging that portion of the fuel that is non-combustible matter, commonly known as ash.

4—A source of oxygen supply sufficient in amount, and at a pressure sufficiently high to overcome all of the resistances offered in the various conduits, as well as in the stoker itself and through the fuel bed structure.

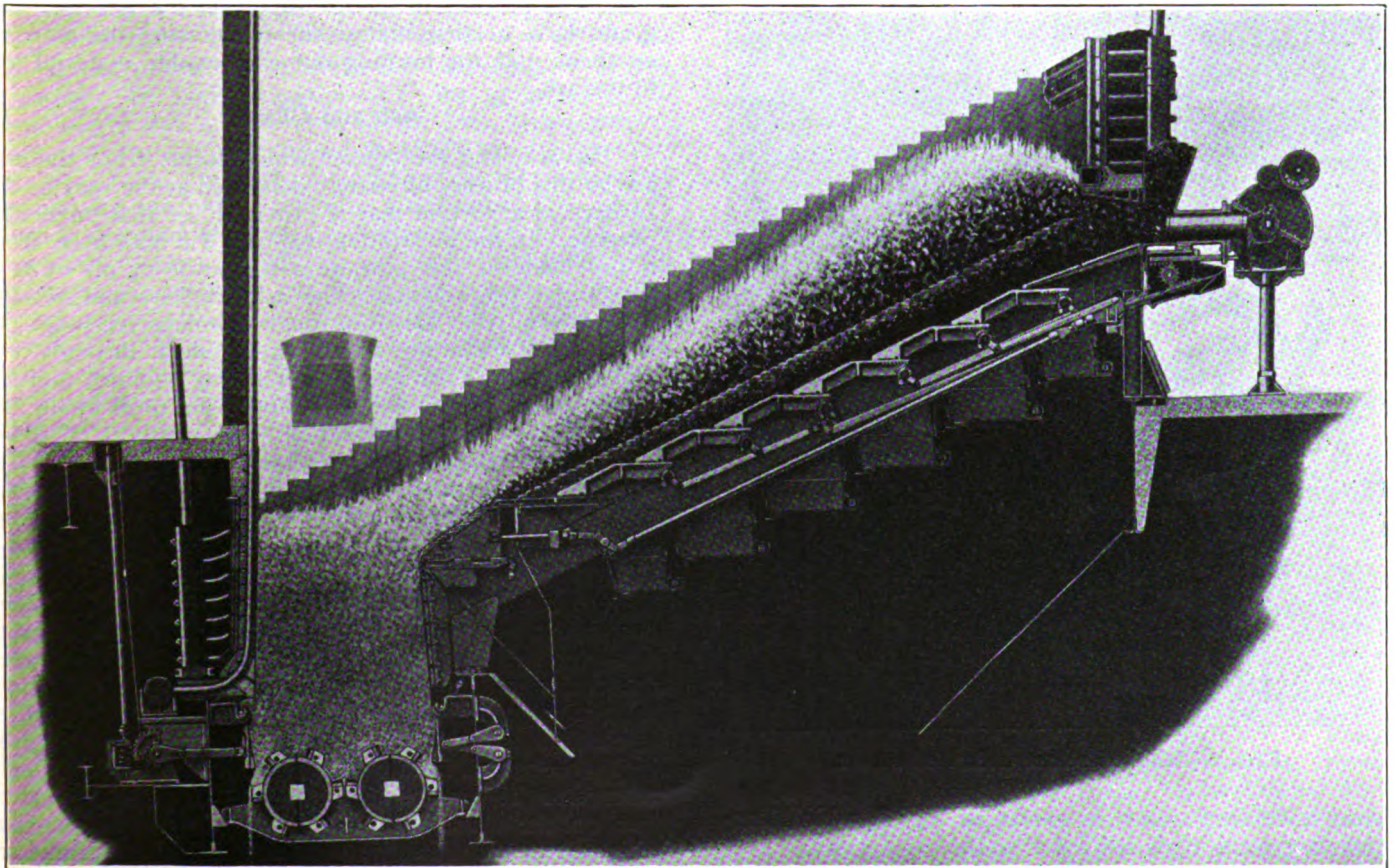


FIG. 1—Stoker section of Taylor unit, with automatic control of air, graduated fuel feed and heat absorbing elements.

5—Adequate means for directing the flow of oxygen, or air, to insure a positive and uniform supply at all points where required, and in just such quantities as required.

6—Adequate controlling means for varying those quantities for varying rates of operation, and also for varying characteristics of fuel.

7—The design must contemplate adequate provision against abrasion by the fuel and ashes; adequate protection from the temperature effects of the fuel bed, the hot ashes and clinkers; adequate strength to resist the effects of excessive coking or clinking.

8—The consumption of power for driving the moving parts of the combustion equipment should be small, and the air pressure should be kept to as low a point as possible to reduce the power required to supply the air.

The design must also contemplate a proper furnace construction around the stoker with the following considerations in mind:

9—Wall construction enclosing the stoker, adequately designed to resist temperature and clinking effects and certain classes of abrasion.

10—Furnace enclosure adequately designed to accommodate the heat liberated by the combustion processes, and the proper flow of gases before they perform their principal mission and the heat is converted into useful work.

The Stoker Described

The manner in which these requirements are met is illustrated by the longitudinal section through a multiple

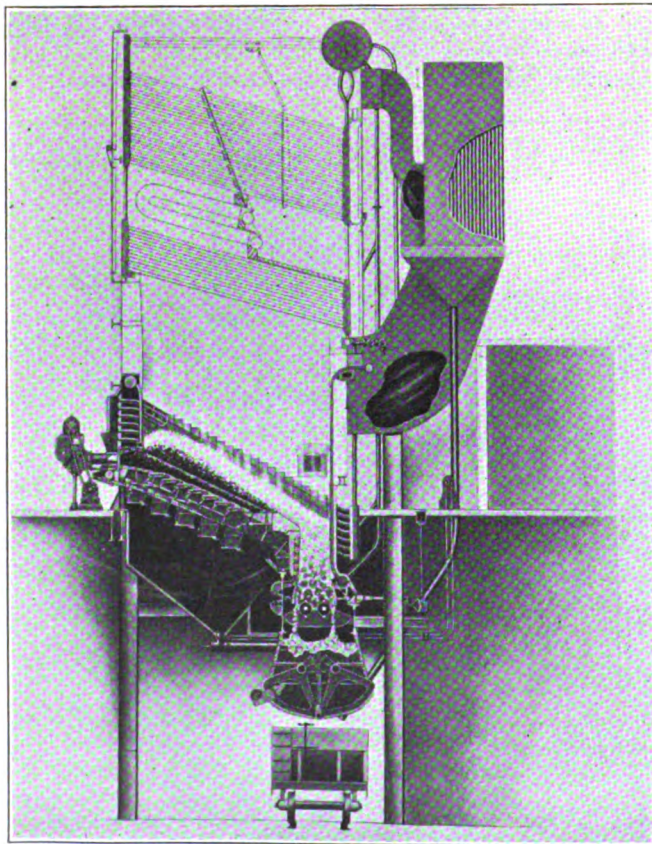


FIG. 2—Multiple retort underfeed stoker.

retort underfeed stoker, as shown in Fig. 2, which illustrates a typical modern Taylor stoker.

The coal is delivered to the stoker hopper. Reciprocating cylindrical rams take the charge of coal from the

hopper and force the charge of coal into the entrance throat of the retort. The charge of coal is compressed tightly and forced into the coal already in the retort, causing it to rise.

The coal would all rise at the front of the retort if it were not for a very complete system of distributing pushers, which operate simultaneously in conjunction with the primary rams. The movement of these distributing pushers is so regulated in amount and speed as to cause such an amount of fuel to rise over each portion of the retort as can be burned over that portion.

Alternating between retorts are rows of tuyeres, which bring the air into the fuel at a point where the fuel is issuing from the retort, in proper direction and quantity. The fuel which is in process of coking and final stages of burning, completely covers both the retort and the tuyeres in a solid and homogeneous mass.

The fuel bed itself is continuous from one side of the furnace to the other, as the fuel rising from the top of one retort, meets the fuel rising from the top of an adjacent retort over the tuyeres. The ash, which is the residue of the combustion process of coal, is, of course, to be found on the top or upper surface of the fuel bed. Due to the downward slope of the fuel bed combined with the breathing action by means of intermittent feeding, the ash gradually descends to the rear, in, of course, increasing concentration.

In the process of burning, much or all of the volatile matter in the fuel is liberated over the retorts. There is left a devolatilized coke and ash. For the further burning of the devolatilized coke, and the discharge of ash at the rear of the furnace, a peculiar and special form of inclined grate is provided.

In this grate, air is supplied to the fuel at a lower pressure than prevails in the air supply to the retorts. The grates have a horizontal stroke for moving the material on them, and for burning out combustible material left in the ash.

Ash and Clinker

The ash, and the clinker which forms from the ash, are by this process ultimately deposited at the rear of the furnace in a portion that is provided for that particular purpose. In the illustration that you will note here, there is provided for this purpose a receptacle or pit of very substantial proportions. The ash, clinker, and residue coke descend very slowly through this deep receptacle, to which small quantities of air are supplied, through ventilated walls, the ash and clinker slowly cooking, and the combustible material slowly disappearing until finally the ash and clinker are deposited on heavy crushers, after the combustible has almost completely disappeared. The crushers are operated at a rate which conforms with the rate at which the whole process takes place, so that the ash and clinker are removed at a rate that will carry out the process successfully.

The air that is necessary not only to burn the fuel, but also to maintain the life of the machine that so successfully performs this function, is supplied by forced draft fans and supplied to the stoker through large ducts, to an air chamber which is shown in the figure, and which is continuous under the entire stoker. This air may be highly preheated, in fact, the use of preheated air not only returns to the furnace heat units that otherwise would be lost up the stack, but also improves combustion conditions, extends the active portion of the fuel bed and results in a greater heat release per square foot of grate area than when cold air is used.

Four Fuels Burned Under Boilers

Equipment and Operation of the Blast Furnace Power House
Steam Generating Equipment Is Described—Blast Furnace
Gas, Powdered Coal, Coke Gas or Oil May be Used

By J. R. MILLER

SELDOME does one find boilers so designed and equipped that any one of four fuels may be burned singly or in combination with any or all others as conditions may demand. In several installations blast furnace gas and powdered coal are burned singly or simultaneously, but in few instances is a third or fourth fuel available. At the blast furnace power house of the Otis Steel Company's Riverside Works in Cleveland powdered coal, blast furnace gas, coke gas and fuel oil may be used as desired, hence it is possible to meet practically any fuel emergency which may arise.

This ability to use any of several fuels also has an economical advantage, as for instance, should an excess of coke gas become available as a result of the shutting down of any of the coke gas burning equipment, the boilers could immediately absorb this excess, thus obviating the necessity for bleeding the gas to the atmosphere, which would otherwise have to be done.

Since this power plant has been in operation for some years sufficient time has elapsed to give assurance that the results secured are representative for the equipment. Furthermore the company engineers have been enabled to appraise from past performance the success of the installation and reach a decision as to the most acceptable design for future additions.

At the present time there are two systems in operation. The high pressure—250 lbs. gage and 150 deg. superheat serves two 10,000 kw. turbo-generators, one turbo-blower rated at 45,000 cu. ft. per minute at 30 lbs. pressure, a 10,000 g.p.m. service water pump and the boiler and unit auxiliaries. This line is also connected through a desuperheater to the low pressure system which is normally supplied with saturated steam from an old boiler house at 150 lbs. pressure and still serves the five blowing engines, only three of which are operated at one time, skip engines, hydraulic pumps and other miscellaneous steam driven equipment incident to a blast furnace. This low pressure system is, however, being gradually replaced by the more efficient and economical high pressure equipment.

The High Pressure Steam Plant

As originally constructed the high pressure plant consisted of four 834 hp. Babcock & Wilcox Stirling boilers fired with blast furnace gas, as illustrated in the design shown in Fig. 2. After these boilers had been in operation for a while, two of them were equipped with Fuller-Lehigh flare type powdered coal burners. Later two 822 hp. Union Iron Works Stirling boilers were added and these were also provided with similar powdered coal burners. Within the past year one of the two boilers not supplied with coal burners was equipped with Peabody turbulent powdered coal burners operating with forced secondary air. This permits the use of coal simultaneously with the blast furnace gas at high ratings, which is not

possible with the flare type natural draft burners as a furnace pressure exists when the blast furnace gas is burned at ratings above 150 per cent. Preparations are now being made for the installation of similar burners on the other boiler.

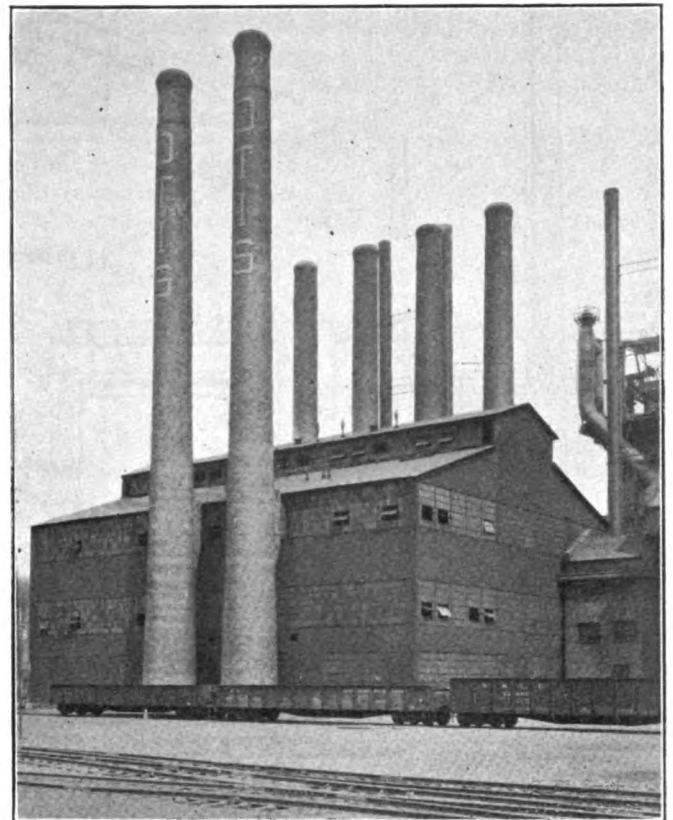


FIG. 1—View of the boiler house with blast furnace in background.

A new boiler is under construction at the present time. This boiler is to be a Babcock & Wilcox cross drum, 16 tubes high and 26 tubes wide and will be rated at 1088 hp. Powdered coal will be the only fuel and will be fired through two Bailey-Tenney burners, each of which will be capable of burning 7,000 lbs. of coal per hour. The two sides and the rear walls will be formed by Bailey water cooled refractory blocks, backed with insulation. The ash will be discharged through an Allen-Sherman-Hoff hydro-jet sluicing system which will also be extended to the two adjacent boilers.

This type and size of boiler and furnace were selected largely because of the possibility of getting a unit of approximately double the steaming capacity in the same boiler house space, thus eliminating an extension of the building for the next addition, and the fact that powdered coal will be the only fuel.

Water for the boilers is procured from the city mains and when treated with soda and sodium alumi-

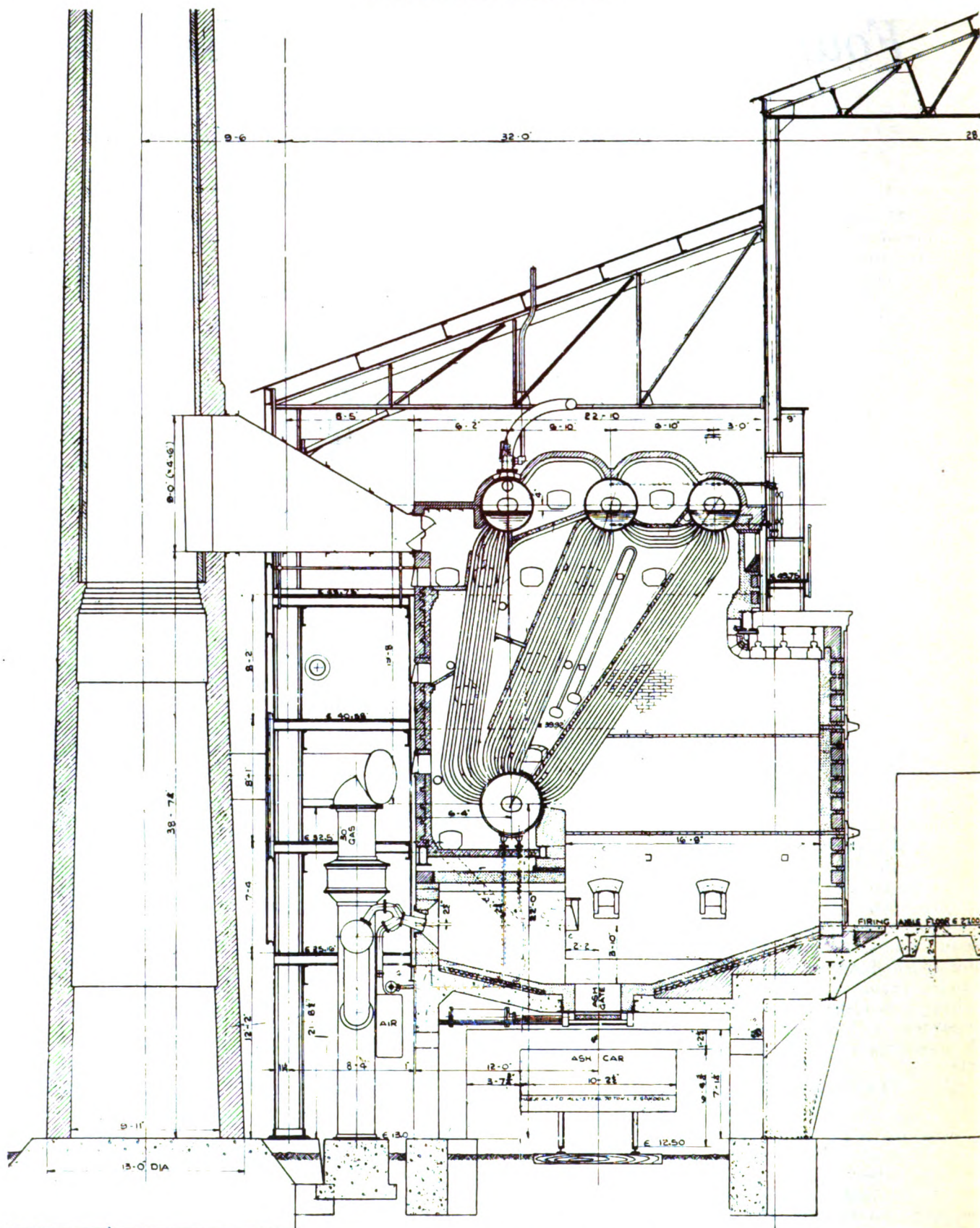


FIG. 2—Cross section of boiler and stack.

nate gives no deposit of a troublesome nature on the boiler tubes. This is quite evident from the fact that during the year 1927 only 17 tube replacements were necessary in the entire boiler house, and there were but two forced shut-downs, only one of which was

the result of tube trouble. The boilers are kept on the line for from 10 to 12 weeks between cleanings.

The water flows through a venturi tube to the boilers where the quantity admitted is controlled by a regulator of the Copes type. Three feed water pumps

Principal Power Plant Equipment at Otis Steel Company's Blast Furnace Plant

Boilers, Superheaters and Accessories

- 4 B. & W. Stirling type boilers, 8,340 sq. ft. each. 250-lb. gas pressure.
- 4 B. & W. superheaters (150 deg. sup.).
- 2 Union Iron Works Stirling type boilers, 8,220 sq. ft.
- 2 Elesco superheaters.
- 8 Diamond soot blowers in each boiler.
- Copes feed water regulators.
- Golden Anderson non-return valves.
- 4 Boilers equipped with Fuller Lehigh flare type powdered coal burners.
- 1 Boiler equipped with Peabody turbulent burners. All boilers fitted with both gas and coal burners.
- 4 Boilers with Steinbart blast furnace gas burners (2 to each).
- 2 Boilers with Bradshaw aspirating gas burners.
- 2 Sturtevant primary air blowers, 12,500 c.f.m. at 7-in. steam pressure.
- 4 Sturtevant secondary air for gas burners, 25,000 c.f.m. at 6-in.
- Bailey boiler meters with stack temperature recorder.
- Venturi feed water meter.
- Bristol recording instruments on steam pressure, gas pressure and feed water temperature.
- 1 Cochran open feed water heater.

- 3 Dean Hill boiler feed pumps, 900 g.p.m. at 300-lb. pressure.
- Individual stacks, Kellogg radial brick, 150 ft. x 6 ft. 6 in. at top.

Coal Pulverizer Equipment

- 1 Fuller ball screen mill of 6 tons per hour capacity.
- 1 Raymond roller mill, 6 tons capacity.
- 1 Fuller drier, 15 tons per hour.

Prime Movers, etc.

- 2 General Electric Company turbo generators, 12,500 kva. each, 25 cycle, 6,600 volts.
- 1 Ingersoll Rand 84-in. barometric condenser.
- 1 Elliott low level jet condenser (14,000 g.p.m. water).
- 1 General Electric Company turbo-blower, 45,000 c.f.m. at 30-lb. pressure.
- 5 Mesta blowing engines, disconnected compound.
- 4 De Laval condenser pumps, 10,000 g.p.m. each (motor driven).
- 2 Motor driven service water pumps, 8,350 g.p.m. at 160 ft. head.
- 1 De Laval turbine driven pump, 12,000 g.p.m. at 160 ft. head.
- 2 De Laval motor driven gas washer pumps, 3,500 g.p.m. at 120 ft.
- 2 De Laval turbine driven pumps, 1,500 g.p.m. at 370 ft. head.

sufficient to develop a pressure of 300 lbs. and with a combined capacity of 2700 gallons of water per minute force the water through the system.

Each boiler is provided with a superheater of a size sufficient to raise the steam temperature 150 deg. F. at a pressure of 250 lbs. which is the pressure normally carried. Appropriate instruments record the steam flow and the temperatures and pressures.

As will be noticed in Fig. 1 the disposal of waste gasses is effected by means of individual stacks instead of a stack, or stacks, common to several boilers. These stacks are built of radial brick to a height of 150 ft. and with an inside diameter of 9 ft. 11 in. at the base and 6 ft. 6 in. at the top.

The ash which forms in the furnaces of the boilers burning powdered coal is allowed to drop through openings in the base of the hopper bottoms and into cars placed below these openings. Doors operated by suitable mechanism control the flow of ash from the furnaces to the cars.

Fuels Used and Their Sources

Blast furnace gas is furnished by two 500-ton capacity furnaces, one of which may be seen to the rear of the boiler house in Fig. 1. Of the total amount of gas generated by the two blast furnaces about 30 per cent is used by stoves for heating the blast. Thirty-eight per cent is used in the four boilers above mentioned and 32 per cent in the older boiler house. The gas, with a B.t.u. content of 95 passes from the furnace through a dust catcher and is then washed before being delivered to the burners in which a pressure of

from 1 in. to 3 in. is maintained. Each boiler is equipped with two burners located in the back wall of the furnace. These burners receive their air supply from four fans which individually have a capacity of 25,000 cu. ft. per minute. A rating of approximately 160 per cent is carried on the boilers at an efficiency of about 70 per cent. For every pound of coke burned in the blast furnace an average of 3 lbs. of steam are generated in the boilers from the resulting gas. With $3\frac{1}{2}$ in. pressure in the burner 225 per cent of rating can be maintained but at this rating the stack loss is increased about 5 per cent over 160 per cent rating.

About 500 ft. from the power house is the building in which is located the coal crushing, drying and powdering equipment. For pulverizing the coal there are at present two 6-ton pulverizers, but as these machines will be inadequate to meet future demands a third 6-ton machine is being added. When powdered the fine coal is placed in a hopper from which it is discharged into tanks and from these driven by compressed air into a transport pipe line through which it passes to 25-ton hoppers above the furnaces in the power house. From the 25-ton hoppers the coal flows into six feeders and then into the pipes leading to the burners placed in the front walls of the furnaces. Care is taken that the coal which is a slack of about 36 per cent volatile content is well dried and that the fineness approximates 77 per cent to 80 per cent through a 200-mesh sieve.

When burning powdered coal a rating of 200 per cent is usual, but this can be raised to 275 per cent

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The Trend of Power Plant Design

Increased Boiler Pressures and Higher Degrees of Superheat in
Modern Installations Have Brought About Improvements in the
Design of Boiler Settings and in the Methods of Burning Fuel

By F. H. DANIELS*

THE trend in design of the modern power plant is towards higher steam pressures, higher superheat, and larger units. Boilers operating at pressures of from 150 to 250 lbs. which have been considered good practice for some years in industrial plants are being rapidly replaced with boilers to operate at higher pressures. Common usage today calls for pressures between 400 and 650 lbs. with a number of plants going as high as 1,200 and 1,400 lbs. initial pressure. High pressure turbines exhaust into lower pressure systems with a considerable gain in economy and capacity at a comparatively low cost.

The use of high steam pressures, high superheat and large units has greatly decreased the relative size of the turbines and turbine rooms. In order to maintain a balance between the size of the turbine room and that of the boiler room, a much greater steam output per square foot of floor space, than was standard practice several years ago, must be obtained. This means not only an increase in the rated boiler horse power per square foot of floor space but also an increase in the per cent of over-rating at which the boiler is to operate. Stokers and pulverized fuel burning systems are consequently demanded with a larger fuel burning capacity as well as higher operating efficiency.

To bring about the desired results boilers are made in larger sizes, as when boilers get larger and larger the amount of floor space required by them become less and less per unit of boiler capacity. A 1,000 h.p. boiler does not require twice the space under it that a boiler rated at 500 h.p. does. High ratings can now be obtained from the boilers due to improvements in furnace construction, notably the now very general use of water cooled walls, the development of mechanical stokers and pulverized fuel system. This paper will be devoted to a few of the recent improvements which have been made to furnace designs and fuel burning equipment.

Boiler furnaces years ago were relatively small and in spite of the high rates of combustion, brickwork maintenance was not excessive. With this type of setting it was difficult to obtain high efficiencies because of incomplete combustion. With a low set boiler, furnace temperatures are low and combustion is seldom complete when the gases enter the boiler. If high efficiency is to be obtained there must be a thorough mixing of the lean and rich gases leaving the fuel bed or the pulverized coal burner. With a low set boiler it is almost impossible to obtain this mixing or turbulent combustion.

Changes in Type of Boiler Settings

In order to obtain higher efficiencies the setting heights of boilers have been rapidly increased. The enlarged furnaces permitted better mixing of the gases and more complete combustion before the gases entered the boiler tubes. Less excess air may be used under these conditions with the result that higher furnace temperatures are obtained. High furnace temperatures are desirable as

they facilitate rapid combustion resulting in complete combustion in the minimum of space. The use of high boiler settings, high furnace temperatures and better combustion however proved very destructive to the ordinary refractory wall. If combustion alone were to be considered, an uncooled refractory wall would be the most satisfactory, however, the excessive maintenance demanded that some means of cooling be evolved. Before extreme efficiencies were required, excess air was admitted in order to decrease the furnace temperatures, this of course decreased the efficiency.

This condition together with the high boiler ratings which have to be obtained in the modern plant have brought about the rapid adoption of some form of water cooled surface. Water cooling consists of either exposing bare tubes to the furnace or covering them with refractories or iron castings or in the installation of radiant type superheaters. The exact amount of water cooled surface in relation to the size of boiler and furnace does not seem to have become definitely fixed. It is apparent that if a boiler is to operate at both extremely high and low ratings that the matter of water cooling can be overdone so as to make operation at the lower ratings inefficient due to the retarding effect which the water cooled surface will have upon combustion at the low ratings. A large number of plants at the present time are using water cooled surface on either two or three walls.

One of the newer large central station installations is that of the Kearny plant of the Public Service Gas and Electric Company. Here the furnace is completely surrounded with water walls, which differ from standard practice, in that they extend to the top of the boiler, see Fig. 1. The tubes are uncovered except for a belt of three feet high around the stoker and six feet high in the ash pit. This belt is covered with bare cast iron blocks. The extension of the side walls from the top of the furnace to the top of the boiler proved to be cheaper in total cost than the corresponding thick brick wall with girder and buckstays. It will recover enough additional heat to improve the efficiency about $\frac{1}{2}$ per cent. This construction has a number of other construction advantages and undoubtedly it will be more generally used in the near future.

An example of the use of water cooled surfaces in a typical industrial plant using pulverized coal is that of the Fitchburg Paper Company's plant at Fitchburg, Mass., see Fig. 2. The installation consists of a 1,000 h.p. boiler fired with pulverized coal. Two horizontal flare type pulverized coal burners are used per boiler. The furnace is 13 ft. 8 in. from front to rear wall by 19 ft. 4 in. wide. The furnace volume is approximately 6,600 cu. ft. The front wall is air cooled. Radiant type superheaters are installed in the side walls. These superheaters have an area of 190 sq. ft. In front of the first row of boiler tubes there is a slag screen having an area of 430 sq. ft. This installation has proven very satisfactory. The amount of water cooled surface being sufficient to protect the walls from excessive maintenance

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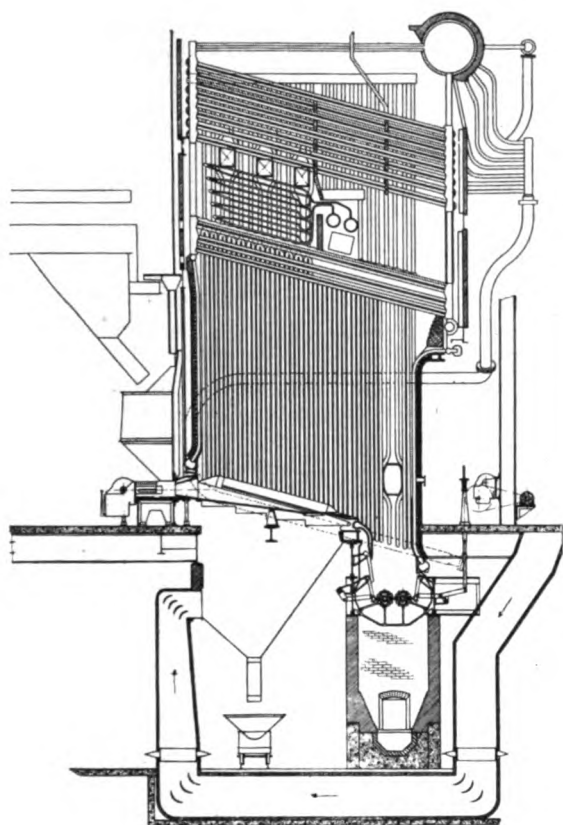


Fig. 1

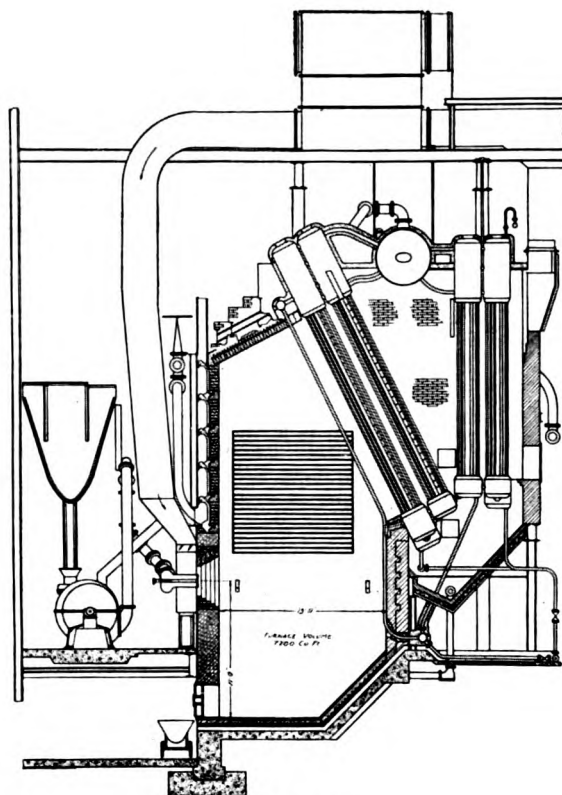


Fig. 2

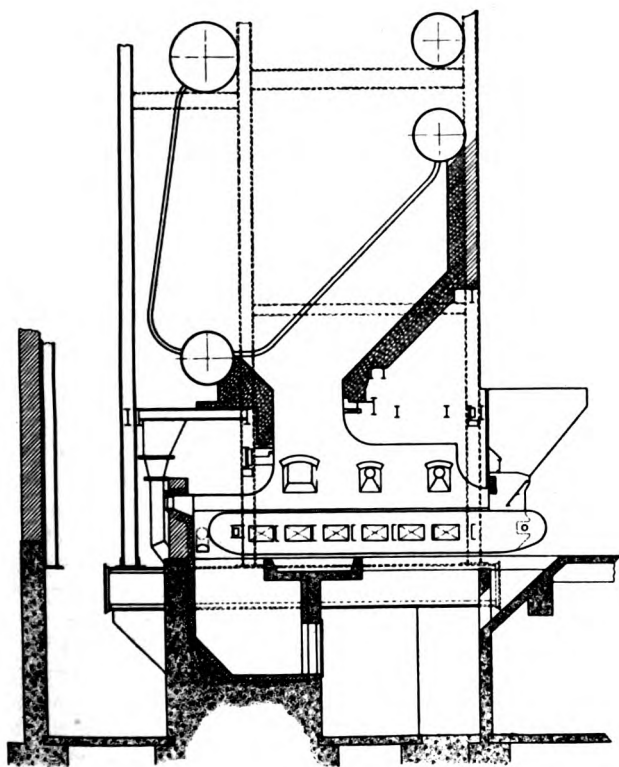


Fig. 3

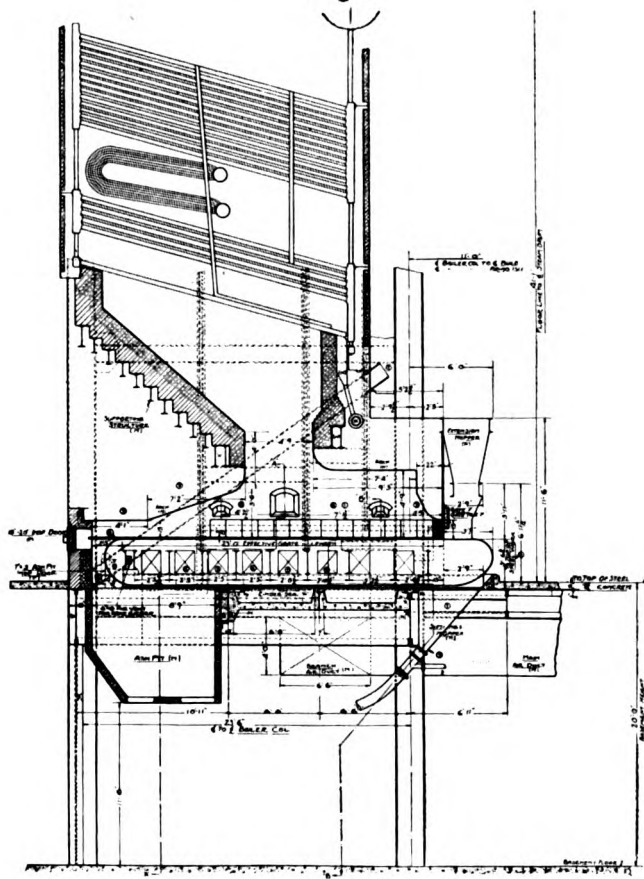


Fig. 4

FIG. 1—Furnace design using all water cooled walls with cooling tubes extending to very top of boiler. FIG. 2—Furnace design using radiant type superheater in side walls. FIG. 3—Typical furnace design for burning lignite. FIG. 4—Typical furnace design for burning anthracite.

covering the ratings at which the boiler is operated and permitting the use of furnace temperatures sufficiently high for efficient combustion.

Another factor which has had a part in the increase of boiler ratings and efficiencies is the extended use of air preheaters. Air preheaters not only recover waste heat from the fuel gases but they also accelerate combustion. Preheated air has a marked effect on combustion both with stokers and pulverized coal. Ignition naturally is earlier, combustion is more rapid and complete, flames are shorter and furnace temperatures are higher due to increased speed of combustion. Due to their simplicity and low maintenance it seems safe to predict further increase in the use of them during the next few years.

Types of Stokers for Various Fuels

In this country the underfeed stoker or pulverized coal has become standard equipment for the burning of the higher grade eastern bituminous coals. In England and Continental Europe, traveling grate or chain grate stokers, mostly forced draft, are in universal use where high ash and low grade coals are burned. In this country, they have practically the same universal use for burning anthracite, the coals of the middle west, the lignites and coke breeze. We shall discuss some of the recent improvements first to underfeed stokers, then traveling grate or chain grate stokers and then pulverized coal equipment.

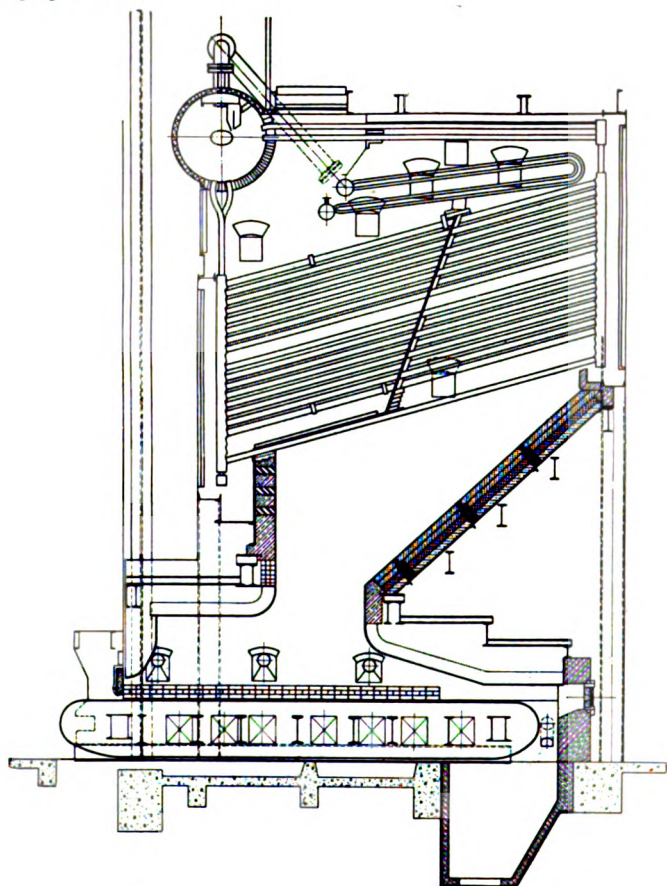


FIG. 5—Typical furnace design for burning coke breeze.

There have been many developments and improvements to mechanical stokers in the past few years making possible higher efficiencies and greater coal burning capacities. It was not many years ago that underfeed stokers were scarcely ever made in lengths over 10 or 11 ft. It is true that at some installations, two of

the shorter stokers were placed back to back in order to obtain a larger grate area under the boiler. Today these stokers are built in lengths exceeding 20 ft., so as to occupy the entire space under the boiler. This obviously has increased the fuel burning capacity. This increase in length of the stokers has indicated the desirability of certain improvements in design.

With stokers of this unusual length it is apparent that some effective means must be employed to obtain control over the fuel bed. This is accomplished by the design of the coal feeding mechanism both as to the entry of the fuel to the furnace and down the fuel bed. For this purpose conveyor tuyeres or auxiliary pushers under the fuel bed are used.

With stokers of this length the amount of fuel burned per retort is much greater than with the shorter stokers. It is apparent that if plungers of the same diameter as were used with the shorter stokers were used with the longer ones that the driving mechanism would have to operate at much greater speed with the result that the maintenance of these parts would increase materially. In order to overcome this difficulty plungers having a greater diameter and stroke have been adopted. However, the use of larger plunger brings about another difficulty in that the ratio of area of the tuyere blocks to the retort area is decreased and with the high capacities required it is necessary to have just as much of the stoker active as possible. This difficulty has been overcome by making the first few tuyere blocks at the front of the stoker narrower and then using tuyere blocks of greater widths throughout the remainder of the stoker.

Air for Combustion

Increase of the stoker length demanded some means of controlling combustion throughout the length of the stoker. The best means of accomplishing this result is to afford means of controlling the air to the different zones into small air zones under damper control from the boiler sides. Also provision is made in some stokers to admit air over the fire in the front of the stoker to provide for the complete combustion of the rapidly evolved volatile matter. This air also is under damper control from the front of the stoker.

The use of preheated air has resulted in improvements in economy, however, it has introduced some new problems in stoker design. In the first case some means must be employed to properly take care of the expansion and contraction caused by its use. Then preheated air will occupy greater space for the same weight of air than will cold air. This means that additional tuyere area has to be provided by either increasing the number of tuyere openings or increasing the size of the ones used in order not to increase to too great extent the velocity of the air through the tuyeres. The use of preheated air gives more activity to the fuel bed and promotes more rapid ignition and combustion so that it is even more necessary to have a uniform fuel bed or excess air is bound to occur. Stoker maintenance is kept low due to the cooling effect of the air passing over the superstructure and through the tuyeres. With preheated air this cooling effect is greatly reduced so that more effective cooling must be obtained. This higher temperature also tends to weaken the superstructure of the stoker so that some of the stoker manufacturers have increased materially the size and strength of this part of the stoker.

In order to reduce the loss due to combustible in the ash, clinker grinders have been adopted by all of the big underfeed stoker manufacturers. Clinker grinder

pits are made much deeper than they were several years ago and on the longer stoker a double roll grinder is ordinarily used. The mechanisms used to drive the grinders have been developed to give independent operation of the two grinder rolls so that different speeds can be used on them. The construction of the grinder pits have been improved so that they are ordinarily made up of large frames on which are located small cast iron sections so that maintenance is reduced to a minimum. The construction is such that air is admitted to the grinder pit to assure the burning of practically all of the carbon in the ash. This air is ordinarily under the control from the boiler side.

For burning anthracite, the high volatile coals of the middle west, lignites and coke breeze, the chain grate or traveling grate stoker has been quite generally adopted, see Figs. 3, 4 and 5. Several improvements have been made to this type of stoker which has improved results. The grate construction has been improved so that siftings are reduced to a minimum. Slight changes in the grate construction have given better air distribution and operation. Improvement in the construction at the sides has reduced the tendency to obtain air leakage at these points.

Probably the greatest reason for the improved results being obtained from this type of stoker is the greater knowledge of the proper arch construction and the adoption of the rear arch. Arch design must be slightly different for an installation burning coke breeze, anthracite and lignites, however, a compromise can be struck to give satisfactory operation with more than one type of fuel. The attached arch designs have given very satisfactory performance with these different fuels.

Traveling and chain grate stokers are now built in large sizes to equip the bigger boilers. It is not unusual to find them over 20 ft. wide and long. In some instances, in order not to make the stoker too wide, two narrower stokers are placed side by side with a low bridge wall between them.

The use of preheated air is being rapidly adopted to their use and especially so when burning lignites or other high moisture fuels. A few lignite installations when preheated air is not available use an arrangement for drawing gases from the last pass of the boiler and blowing them into the first compartment of the stoker for rapidly drying the fuel so as to obtain early ignition. The use of preheated air has required a few adjustments in the construction of the stokers. Present practice seems to indicate that the traveling grate stoker is best suited for use with preheated air due to the fact that the grate surface itself merely carries the fuel bed as the link mechanism takes all of the driving stress. The link mechanism is at least five or six inches below the grate surface and consequently the additional heat of the air does not materially effect it.

Pulverized Coal

Progress in the burning of pulverized coal has been very rapid during the past few years due to some extent to the rapid adoption of water walls making possible the use of rapid combustion and high furnace temperatures. The trend in pulverizers seems to be definitely towards the use of unit pulverizers regardless of the size of installation, due to lower first cost and maintenance as compared with the central system. Another reason for the preference of the unit system is the fact that no dryer is required even for the wetter coals. The latest practice is to admit preheated air to the mills thereby drying the

coal as it is pulverized. Turbulent short flame burners set horizontally seem to be rapidly replacing the long flame burners firing vertically with the familiar U shaped flame. The use of short flame turbulent burners enables a very high combustion rate per cubic foot of volume and greater combustion efficiency.

Big improvements have been made in the construction of different pulverizers. These improvements have resulted in much lower maintenance, greater reliability, lower power consumption and greater reliability. In the selection of a pulverizer these different factors must be carefully considered in order to select the most efficient system, combustion efficiency, power consumption and maintenance being duly considered.

Because of the foregoing improvements in furnace design and fuel burning equipment combustion efficiencies today in the newer installations are averaging well over 80 per cent and when air preheaters and economizers are used efficiencies are often over 90 per cent. When these results are compared with the results which were considered excellent not more than five or six years ago, it is very easy to realize the tremendous strides which have been made in combustion equipment.

Steel Plant Boiler Firing Flexible

(Continued from page 783)

enough gas to carry a rating of 225 per cent on each boiler. Automatic control equalizes the gas and air pressure in the burners. Test results are given in Table II.

Stoker Fired Boiler

Besides the five boilers equipped to burn powdered coal and gas, a sixth boiler has been erected over a chain grate stoker having a grate area of 237 sq. ft. On this stoker coke breeze from the company's by-product coke ovens is burned with an efficiency that gives an average CO₂ content of 14 per cent in the waste gases. A rating of over 300 per cent can be reached on this boiler. The fan supplying air to the stoker has a capacity of 27,000 cu. ft. per minute and is driven by a geared steam turbine.

All six boilers discharge their waste gases into a stack with an inside diameter at the top of 18 ft. 9 in. and with a height of 365 ft.

Four Fuels Burned Under Boilers

(Continued from page 789)

for 30-minute periods, or to 240 per cent for 24-hour periods without any detrimental effects to the furnace walls. At 200 per cent rating the efficiency will average 75 per cent and the CO₂ content of the waste gasses will vary from 10 per cent to 12 per cent. The equivalent evaporation per pound of coal over a monthly period is 10.4 lbs. of water.

The fuel oil is burned only in an emergency, but is at all times available for use at instant notice. It is pumped from a storage tank of 10,000 gallons capacity located nearby the boiler house. Duplex pumps force the oil through a circulating system to the burners at a pressure of 180 lbs.

Besides the power house just described there are two others at the Riverside plant but both of these contain equipment of a comparatively inefficient type.

Steel and Beauty

By CHARLES LONGENECKER

IN the manufacture of steel, art has received very meagre consideration. The producer of steel has been more concerned with the art of increasing production than with that art which portrays the romantic, the esthetic features of the industry. But it is now apparent that the makers and sellers of steel, and steel mill equipment, are more appreciative of the value of art as a means by which their products and processes may be more attractively presented.

There is in our steel plants, unquestionably, an extensive and alluring field for the artist who can properly interpret and record on canvas, or paper, his impressions of the manufacture of steel; the utilization of the forces of nature in the extraction of iron from its ore and the conversion of this elemental metal into a more adaptable alloy. In no other industry is there the play of forces so appealing to the imagination of the artist for here he finds mass, inert but a symbol of power; motion, controlled but signifying stupendous force; and light, changeable but in all its brilliancy of color. Surely the depiction of the creation of steel calls for all the skill of the artist and offers him an unlimited range for the display of his genius.

To fully appreciate and correctly conceive the romance embodied in steel calls for more than the eye of an artist—there must be a closer acquaintance-ship. The man who paints steel should be somewhat of an engineer and know the anatomy of machines. Such a man is O. Kuhler the subject of this brief sketch.

O. Kuhler was born in 1894, in a home back among the hills bordering the Rhine. His family had been, for several generations, makers of iron so that



he was reared in an atmosphere which created lasting impressions—impressions which had a decided influence on his choice of a profession. He received an education in the technical schools, but although he found engineering of interest, he found greater enthusiasm in drawing and painting the equipment with which he worked. He served as a mechanic, as a designer of automobile bodies, as an advertising manager and, in 1918, as a railroad construction engineer.

In Dusseldorf he established a studio where for some years he devoted his time to artwork in which his subjects were those of a technical character. Here, in one of Germany's most important steel centers, O. Kuhler found an environment admirably suited to his tastes; accordingly he was able to develop his talents with the utmost freedom. That his work did not lack appreciation is attested by the fact that he was frequently called upon to furnish illustrations for both the advertising and editorial pages of the leading technical magazines of Germany, in which country the services of the artist finds extensive expression as an illustrator. Thus O. Kuhler began his career.

Coming to America in 1923, Mr. Kuhler located in Pittsburgh as there he felt he would find the greatest opportunity to practice his profession. He remained in Pittsburgh until this year when he established offices and a studio in New York City.

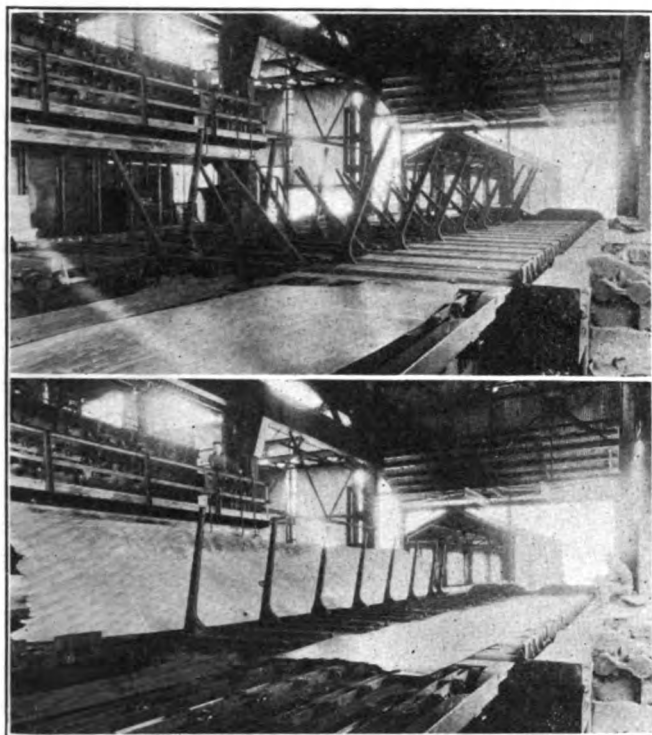
The art of O. Kuhler has been recognized by many large industrial advertisers and steel companies to such an extent that he is rapidly gaining a well deserved prominence as a painter and an etcher. His etchings and paintings have appeared in the advertisements of many magazines and in several art exhibits.



WITH THE EQUIPMENT MANUFACTURERS

Double Plate Turn-Over

Steel plates, after their final pass through the rolls, undergo a series of rigid inspections and a plant lacking the proper equipment for such inspection usually suffers a heavy loss of time in the manipulation and handling of its product. This obstacle to production has been eliminated in the plant of Lukens Steel Company, of Coatesville, Pa., by a mechanical device for the turning over of



steel plates from one side to another to facilitate inspection, known as a "Double Plate Turn-over", which was designed and built by Birdsboro Steel Foundry & Machine Company, Birdsboro, Pa.

Steel plates, after leaving the rolling mill, are fed through an annealing furnace, where they are subjected to a heat treatment which also gives them their final coloring. From the furnace, the plates pass through a leveler, and upon leaving the leveler, a chain-conveyor takes the plates forward and onto what is known as the first inspection table, of Birdsboro design and construction. It is on this table that the plates receive their first examination for blemishes, excess scale, etc. Inspection of the plates is made on one side only on this table and it is now that the turn-over device performs.

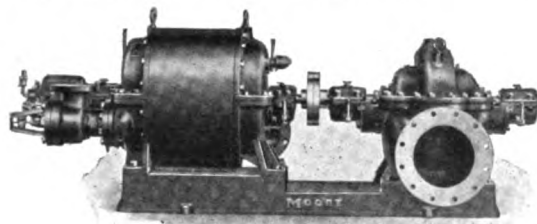
Between every two roller spacings on the inspection tables, or every 5 ft., there are placed movable arms of an approximate 5 ft. length, resting below the top of the rollers in a recess cored in the table aprons. These arms are pivoted at one end on their own bearings, and operated through corresponding arms lying in the opposite direction with segment gears cast onto them and meshed with one another. The arms, whose position rests opposite those of the first inspection table, are operated by a main

shaft on which they are keyed. This shaft is oscillated by a crank movement at one end through a gear reduction unit and a 20 h.p. 600 r.p.m. motor, compound wound. As the operator works his controls, the shaft moves slightly, drawing the arms together, with a scissor-like movement and in an almost vertical position, with a slight lean toward the second inspection table. The operator now returns the arms to their former position and the plate is turned, bottom side up, and rests on a platform of supported rails between the two tables. A second inspection now takes place on the reversed side of the plate, after which the plate is ready for its final turn-over to the second roller table, which is identical with that of the first, with the exception of the direction of travel. A second tier of arms, operating in like manner to that of the first, by a second driving unit of the same horse-power and reduction, turns the plate over again and places it on the second table. The turn-over operation is now complete and the plate moves backward over the rotary shear approach table to the shear.

This "Double Plate Turn-over" is capable of handling plates with maximum dimensions of 84 in. wide, $\frac{1}{4}$ of an inch thick and 37 ft. long. The minimum dimensions of plates handled are 30 in. wide, $\frac{1}{16}$ in. thick and 8 ft. long. The turnover has a capacity of 80 light plates per hour.

Steam Turbines and Reduction Gears

Moore single stage steam turbines are built by the Moore Steam Turbine Corporation of Wellsville, N. Y., in sizes ranging from 5 to 1,000 h.p. and for speeds up to 5,500 r.p.m. For normal steam pressures and temperatures cast iron construction is used while for higher pressures and temperatures all steel construction is used. All turbines are equipped with constant speed and emergency governors, the emergency governor operating entirely independent of the main governor.

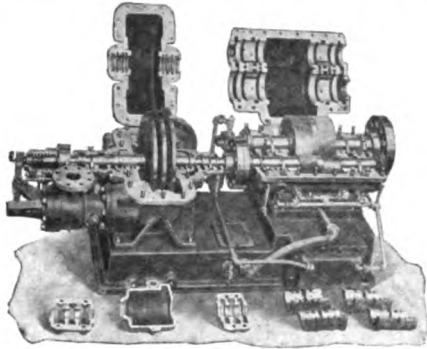


Single stage turbines are especially adapted for driving such auxiliaries as boiler feed pumps, forced and induced draft fans, circulating pumps, coal pulverizers and other auxiliaries where simplicity of construction and reliability are of prime importance. The single stage turbine is usually chosen for forced or induced draft fan drive or any drive where the turbine is required to operate over a large range of speed. For these conditions the single stage turbine is as a general rule more economical than any other type.

Multistage turbines for auxiliary drive have the advantage of considerably lower steam consumption where

the turbines must run at slow speeds or where they can be operated at or very close to the conditions for which they have been designed. The blade life of multistage steam turbines is much longer than that of the single stage as steam velocities are proportionately lower.

For high steam temperatures the entire case of the single stage turbine is made of steel while in the multi-stage all parts coming in contact with high pressure and



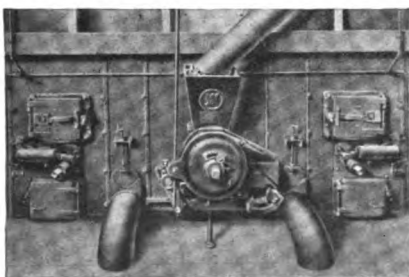
high temperature steam are made of steel. Both types of turbines have center line support for the higher temperatures and are arranged for either water cooling or forced lubrication.

For forced and induced draft fan drive it has been proven that reduction gears having conservative pitch line velocities and low tooth pressures are the most satisfactory. This is due to the severe conditions of operation caused by heat and dirt. All reduction gears are made with large oil coolers and are arranged for forced feed lubrication. The pinion is made of chrome vanadium steel while the gear is made of a high carbon steel. Steel forgings are used on the smaller sizes while forged steel rings shrunk on centers are used in the larger sizes.

New Single Retort Stoker for Industrial Furnaces

The Westinghouse Electric & Manufacturing Company's single retort underfeed stoker with flexible grate motion in combination with power operated dumps has contributed largely to the successful handling of burning fuel, with a minimum amount of labor and attention, in furnaces of wide dimensions.

The illustration shows such an application to the side of an annealing furnace. The firebox extends practically



the whole furnace length, thus insuring uniform heat distribution. An adjustable ratchet screw feed delivers coal to a center retort. An eccentric on the screw shaft imparts motion through a slotted sector lever and cross connecting link to the grate rocker shafts located on each side of and adjacent to the retort. The motion on either side is independently regulated to any desired degree

from minimum to maximum. The ratchet wheel and eccentric run in an oil bath enclosed in a dust proof case.

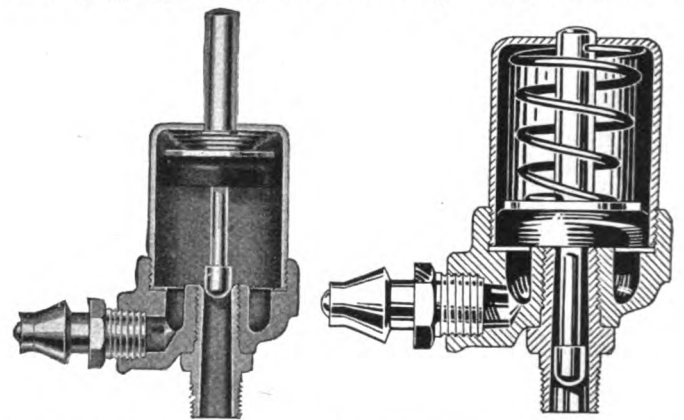
Furnaces for the heat-treating of steel essentially require a thick fuel bed. The flexibility of the grate motion of this stoker effectively handles a heavy fuel mass from the retort to the dump.

The dumps are actuated by single acting plungers operated by steam or air pressure. A weighted lever automatically unlocks the dump lever arm and upon releasing the pressure the dump is lowered. Disengaging the weight from the lever and again applying pressure raises the dump and automatically locks it in normal position.

The complete flexibility of coal feed and distribution combined with an easy and expeditious means of dumping the refuse enables the operator to maintain uniform temperature under the desired conditions of furnace atmosphere uninterrupted throughout the heating cycle.

New Automatic Lubricator

The Balcrank "Uniflow" lubricator has proven its value in many installations, noteworthy among which was its use on the valve rocker bushings on the whirlwind engine in the Ryan monoplane used by Captain Charles Lindbergh in his New York to Paris flight. The accompanying illustration shows very clearly the manner



in which the lubricator works. The cup is filled from the side by a pressure grease gun. The outlet is on the bottom and is tapered to provide for a uniform flow of lubricant as the expansion of the spring diminishes the pressure. No flow of grease takes place until the bearing starts to rotate. When the motion starts, the spring behind the plunger induces a regulated flow. At the top of the cup is an indicator which shows the position of the plunger at any time, and the point when refilling is necessary. The cup is manufactured by the Cincinnati Ball Crank Company of Cincinnati, Ohio.

Portable Air Compressor

Ingersoll-Rand Company, 11 Broadway, N. Y., has added a seventh size to its line of portable air compressors.

This new size (4¾ in. bore by 4 in. stroke) has a piston displacement of 82 cu. ft. per minute. It is intended primarily for use by contractors, public utilities, cities, towns, etc., requiring a unit of slightly larger capacity than the 4¾ x 4 in. 66 cu. ft. machines.

The new compressor, like the other I-R Portables, is equipped with a four-cylinder, tractor-type Waukesha

motor. It is available on broad-faced steel wheels, on steel wheels with rubber tires, on I-R trailer mounting, on Ford or Chevrolet truck, or without running gear for mounting on skids, railway car, etc.

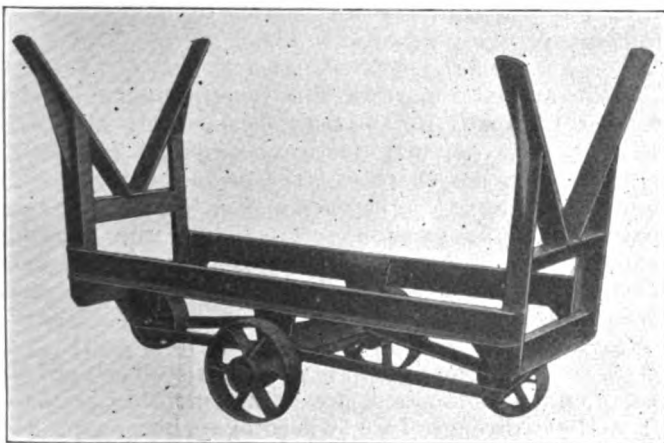
The $4\frac{3}{4} \times 4$ in. unit embodies all the exclusive Ingersoll-Rand features which are found on the other six sizes.

Welded Shop Truck

A new type of shop truck, known as the "Weldsteel" truck has recently been placed on the market by the Pittsburgh Producers Supply Company, of Pittsburgh, Pa. It was originally designed for use in steel mills, particularly for handling wire in coils from wire or nail mills or sheets, plates, and similar material from sheet mills, or any like service. It has also been found suitable for use in other industrial plants where heavy loads are to be moved, such as brick plants, cement mills, crucible works, etc. The truck has a rated capacity of three tons, with a safe overload capacity of 100 per cent. It is very compact, the dimensions being 5 ft. long by 3 ft. overall width, and $3\frac{1}{2}$ ft. overall height.

One of the unique features of the truck is its construction. It is made entirely from steel sections, welded together, no rivets being used. The body proper is made from four heavy channel sections, lap welded to the four angle sections forming the uprights. The uprights are braced by angle sections which are butt and lap welded to them and the frame is given greater rigidity by gusset plates at all four corners. In the case of the truck shown in the illustration V ends are provided so that when it is loaded with wire coils set perpendicularly, a pipe, or steel bar, can be passed transversely through the load to permit its being lifted as a unit by a crane. The V ends are also braced by gusset plates welded to the frame.

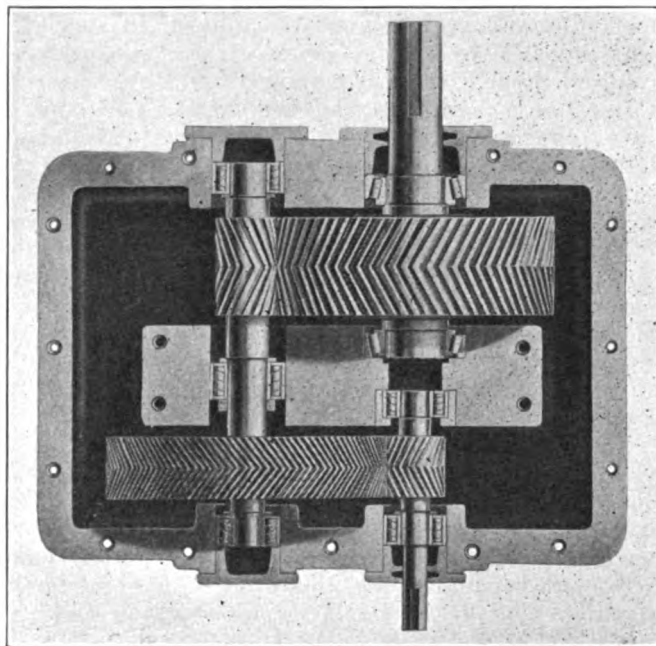
The main axle is supported by a cannon box mounting, made of welded angle sections, and firmly braced by angle sections running to the pilot wheel supports. The wheels are also of welded construction, the tires and hubs consisting of flat sections, rolled to shape, and butt welded.



The spokes are made of heavy flat sections welded to the hub and tire. The wheels on the main axle are equipped with Timken bearings, the choice of which was determined by the service conditions which the truck must meet. In the first place, they reduce the amount of power required to move the truck to a point where two men can handle it when fully loaded. In the second place, they are affected by the expansion and contraction resulting from the wide variations in temperature to which the trucks are subjected in the course of their service.

New Speed Reducing Units

The D. O. James Manufacturing Company, Chicago, makers of all types of cut gearing and speed reducing transmissions, announce the new James generated continuous-tooth herringbone speed reducers, made in both single and double types.



These reducers are new in that they are now fully equipped with anti-friction Hyatt roller bearings on the high, intermediate and slow speed pinion shaft, and Timken roller bearings on the slow speed gear shaft. This latest addition in bearings now gives to James herringbone units an efficiency of the highest rating.

Motors for Use in Explosive Atmospheres

A line of both alternating and direct current motors, built for application where explosive gases, fumes or dust are present, is announced by the General Electric Company. These motors have been approved (as a result of tests) by the Underwriters' Laboratories for operation under such conditions. The motors bear the General Electric designation "Class BU Form JA" and are of a total enclosed design.

The object of the special construction is to reduce the danger that heat, generated inside the apparatus from any cause whatever—whether it be sparking or explosion—will be transmitted to the outside in such intensity as to ignite any gases surrounding the equipment. A two-piece, cast iron exterior is provided, heavy enough to withstand the pressures of an internal explosion and with flanged joints sufficiently wide to cool the flame of any such explosion. No gaskets are used, as it is not intended that the motors should be gas-tight.

The alternating current motors are available in single phase ratings up to 3 h.p. and, in polyphase ratings, up to 15 h.p., at standard voltages and the more popular speeds. The direct current motors may be either shunt or compound wound types with the horsepower ratings from $\frac{3}{8}$ to h.p., also at the standard speeds and voltages.

TRADE PUBLICATIONS

M. D. Mill Motors, form the subject of a 15-page booklet issued by the General Electric Company. These standardized motors are the type installed in steel mills and are designed to conform to specifications prepared by the members of the Association of Iron and Steel Electrical Engineers and by engineers of the motor manufacturing companies. The booklet gives some general information regarding interchangeability, forms available and features of design.

* * *

Fisher Body Corporation Burns Sawdust and Coal at Flint is the title to a reprint distributed by the Combustion Engineering Corporation. Power plant engineers will find much interesting information in this reprint especially if the boilers they supervise burn powdered coal or sawdust. Copies may be obtained by addressing the Combustion Engineering Company at 200 Madison Avenue, New York City.

* * *

Air driven hammers, a product of the Nazel Engineering & Machine Works of Philadelphia, are attractively set forth in a small folder in two colors. Pertinent facts concerning the operation of the hammers, with accompanying illustrations, make plain the advantages of this particular type of forging tool.

* * *

Nichrome Castings, although the title to a 119-page book compiled by the Driver-Harris Company of Harrison, N. J., are given less space than is the description of the art of carburizing and case hardening. The book is in fact a very comprehensive practical treatise on the methods for carrying out these heat treating processes. It is well illustrated and the information is most attractively presented.

* * *

Three publications which contain some very interesting information to those purchasing steels of alloy can be obtained from the Central Alloy Steel Corporation, Massillon, Ohio. Agathon Alloy Steels, a booklet of 143 pages, describes the making and heat treating of alloyed steels besides listing the composition of the several S. A. E. and other steels. It will be a welcome hand book to the steel treater. Agathon Enduro Stainless Irons, as may be judged by the title, presents in compact form much data on corrosion and the properties of steel to resist corrosion. Although containing only 31 pages, the booklet covers the subject quite thoroughly. The Path to Permanence, by text and illustrations, shows the many uses for "Toncan Iron."

* * *

The Adapti Company, manufacturers of Adaptibox conduit fittings, has just issued Supplementary Catalog No. 107-A. This catalog supplement features the company's new line of Adapti-lets, (solid fittings;) also fixture elbows, plug and base receptacles, and self-aligning fixture joints for use with Adapti-lets, Adaptiboxes and all regular standard fittings.

* * *

Belt Dressing Facts is the name of a new 12-page booklet just published by E. F. Houghton & Company, Philadelphia, Pa. It is very well written and it

contains much valuable information on the proper care of belts. The sub-headings are as follows: Belt Lubricant Essential; Slack Belts Undesirable; Loose Belts Waste Power; What a Dressing Should Do; Specially Adapted for the Purpose; Houghton Experience; Packages; Directions.

* * *

Bulletins have been received from the General Electric Company as follows: GEA-233-B, centrifugal air compressors, single stage; GEA-308-A, arc suppressor plates for drum controllers; GEA-752, d.c. motors, type BD constant and adjustable speeds; GEA-835-A, d.c. magnetic controllers for constant and adjustable speed motors; GEA-894, adjustable speed d.c. motors, type CD; GEA-934, automatic throw over panels; GEA-948, d.c. magnetic controllers for constant speed motors; GEA-950, a.c. enclosed starting rheostats used in conjunction with primary switches for slip ring induction motors.

* * *

A circular describing "The No. 80 Firebrick" has been issued by the Babcock & Wilcox Company, New York City. The circular gives test data and service results and also mentions the No. 80 cement, No. 101 moldable mixture, the No. 80 calcine and special shapes. The standard shapes are kept in stock at the East Liverpool, Ohio, plant, and the No. 80 firebrick, cement and moldable stock at Bayonne, N. J.

* * *

Plastic K-N, a chrome ore refractory, has its properties and uses presented in a leaflet prepared by E. J. Lavino & Company, which company manufactures it. This plastic refractory finds application in the repair of furnace linings and hearths. The leaflet illustrates the manner of making furnace hearths, gives instructions for the use of K-N and presents data concerning its shipment, etc.

* * *

Whitcomb locomotives, a product of the Geo. D. Whitcomb Company, Rochelle, Ill., are described in detail in bulletin 2824. These locomotives are fired with gasoline and are for service on narrow gauge railroads.

* * *

The annual report of the Westinghouse Electric & Mfg. Company for the fiscal year ending March 31, 1928 shows a net manufacturing profit of \$14,000,000 and earnings per share of \$6.57 or 13.4 per cent. The figures indicate a slight decrease in business as compared with the previous year when the earnings amounted to \$6.80 per share. The average total number of employees was 41,787, and payrolls exceeded \$70,000,000.

* * *

A 60-page compendium is published by the U. S. Department of Commerce, presenting monthly statistics from 1909 through 1926, where available, on production, stocks, prices, etc., of iron, steel, copper, zinc, tin, lead and their products, including machinery, together with descriptive text, illustrating the use of these data by business concerns.

Presents in handy form a statistical history of the metals and machinery industries monthly from 1909, useful for executives, sales managers, purchasing agents, business analysts and economist in comparing at a glance present tendencies in production, prices, stocks, orders, imports, exports, etc., with those of prior years.

Silica Brick in the Open-Hearth Furnace

Investigation of the Changes that Take Place in Silica Brick
Under Conditions that Are Met with in Service
Particularly in the Open-Hearth Roof

By B. M. LARSEN*

SILICA is one of our cheapest high-temperature refractory materials, but it is far from being a perfect refractory for use in the basic open hearth, where it is an acid oxide more or less surrounded by basic fluxes. Silica brick are, however, admirably adapted for forming arches and supporting loads at temperatures close to their melting point. Also, a silica arch becomes recrystallized to form an unbroken inner surface covered with a glaze that is beautifully adapted for reflecting radiant heat from the flame down on the steel and slag in the furnace hearth. Research has so far failed to uncover any superrefractory that can give much promise of displacing silica brick for such use.

It thus becomes important to understand all of the effects of open hearth service on silica brick. It is fortunate that the various forms of silica and many of the silicate systems have been well studied, so that we have here another very good example of the possibilities of abstract research for furnishing explanations of the many puzzling conditions observed in commercial furnace practice.

Forms of Silica

Solid silica can exist in four main forms, three of them crystalline solids and one an amorphous or supercooled liquid form. Because of the very low rates of change of one form to another, all of these can exist at ordinary temperatures, but only one of them, the crystal form known as quartz, is stable in this range. From 1,600 to 2,680 Deg. F. the crystal form called tridymite is stable, and from 2,680 to 3,110 Deg. F. cristobalite is the stable form. Cristobalite melts at 3,110 Deg. F. to form a very viscous liquid which can easily be supercooled to any lower temperature range, giving the various forms of quartz glass, vitreosil, etc.

When one form of silica is heated in the stable range for another form, the material may either change into the most stable form or may change into both of the other forms in succession, beginning with one nearest in order of stability. For example: Quartz, if heated anywhere in the range of 1,600 to 3,100 Deg. F., tends to change first into cristobalite and then slowly into tridymite, if the temperature is below 2,680 Deg. The presence of fluxing impurities which will dissolve silica tends to hasten all of these changes, especially the formation of tridymite, which always takes place slowly and only by crystallizing out of solution in fluxes. The less stable form always tends to dissolve most rapidly; the more stable form crystallizes out most rapidly, causing a gradual increase in the percentage of the more stable form. Fig. 1, taken from Sosman,[†] shows graphically the stability relations involved, in which the ordinates of the various curves represent the "escaping tendency" or an imaginary vapor pressure of the constituents. These values are only rela-

tive, but obviously the form which has the lowest escaping tendency at a given temperature will be the most stable.

Each crystalline form has also an alpha and a beta form, stable at low and high temperatures respectively, but in contrast to the change from one crystal form to another, alpha-beta inversions occur rapidly and are reversible. In all transformations of silica volume changes occur, the most important being in the changes from quartz to either cristobalite or tridymite, and in the alpha-beta cristobalite inversion.

Cristobalite, being the most stable high-temperature form, has the highest melting point, which is close to 3,110 Deg. F. Tridymite melts slowly at about 3,040 Deg. G., and quartz melts at a still lower temperature, which is probably about 2,680 Deg. F. or lower.

Recrystallization in Silica Brick

Silica brick are made from a mixture of nearly pure quartzite with about 1.5 to 2.5 per cent of lime, burned in a kiln at 2,600 to 2,660 deg. F. for about two days, with slow heating and cooling. The brick then have approximately the following percentage composition: SiO_2 , 96.0; Al_2O_3 , 0.8; Fe_2O_3 , 0.8; CaO , 1.9; MgO , 0.2; and alkalis, 0.3 per cent.

The important change involved in the burning of silica brick is the partial recrystallization of the original quartz

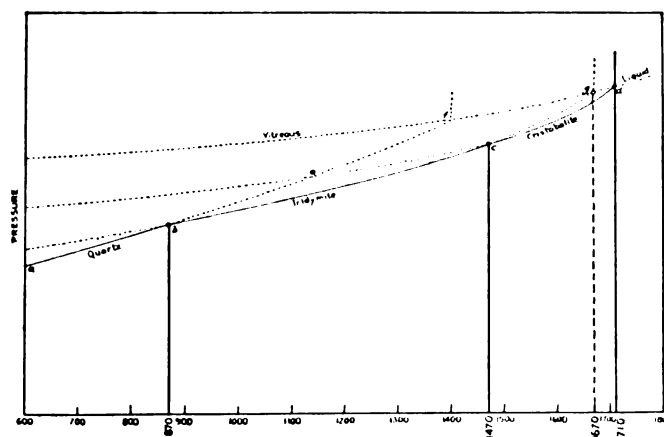


FIG. 1—Imaginary vapor-pressure curves of the principal forms of silica. ab, upper part of the stability range of quartz. bc, stability range of tridymite. cd, stability range of cristobalite. e, metastable inversion point of quartz and cristobalite, temperature unknown. f, melting-point of quartz, temperature not exactly known. g, metastable melting-point of tridymite.

to form cristobalite and tridymite. This change occurs partly by slow inversion of the quartz crystals to cristobalite in the dry state, and partly by solution of the finer quartz crystals in the liquid formed between silica and the lime, iron oxide, and alumina impurities, the quartz crystallizing out of this solution as cristobalite and tridymite. The formation of tridymite is comparatively slow, so that the burned brick are usually composed of 4 to 5 per cent of tridymite, 70 per cent of cristobalite, and 25

*Assistant metallurgist, Pittsburgh Experiment Station, U. S. Bureau of Mines.

†Sosman, R. B., *The Properties of Silica*. Am. Chem. Soc. Mon. Series, Chem. Cat. Co., N. Y., 1927, p. 50.

per cent of unchanged quartz and silicates. The new crystals formed are all interlocked and grown together in a structure well adapted to resist deformation by externally applied stresses, even at high temperatures, so that the ability of silica to crystallize in different forms is really responsible for the load resistance of silica brick in roof arches of high-temperature furnaces. The burned brick have about 28 per cent by volume of pore space, mostly in the form of open pores.

During the burning the brick undergo a permanent expansion of about 10 to 11 per cent by volume. This expansion is caused by the partial change from quartz with a specific gravity of 2.65 to cristobalite and tridymite with specific gravities of 2.33 and 2.27, respectively. Any portions of the brick which subsequently in service change completely to tridymite may undergo an additional permanent expansion of about 5 to 6 per cent. This is the principal cause of the permanent expansion of silica brick arches in service.

Reversible expansions occur in the alpha-beta inversions as follows:

α -quartz to β -quartz—0.9 per cent at 1,060 Deg. F.

α -tridymite to β_1 -tridymite—0.14 per cent at 210 Deg. F.

β_1 -tridymite to β_2 -tridymite—0.2 per cent at 325 Deg. F.

α -cristobalite to β -cristobalite—2.8 per cent at 390-525 Deg. F.

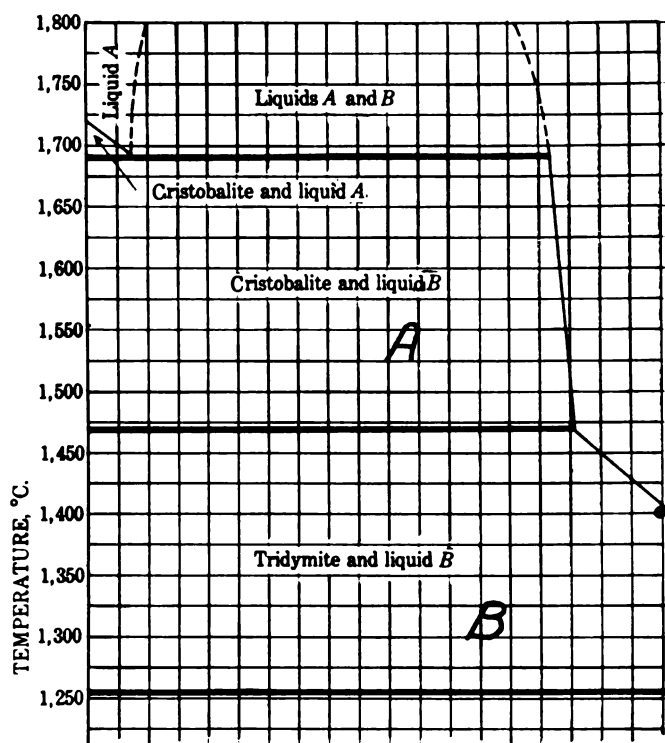


FIG. 2—A portion of the high-silica end of the FeO-SiO₂ equilibrium diagram.

New silica brick, being composed chiefly of cristobalite, expand about 3.5 per cent over a small temperature range, which is perhaps the principal cause of cracking of these brick from rapid heating or cooling at low temperatures. An all-tridymite brick would have the least reversible expansion and would also give no permanent expansion in service. Many efforts have been made to produce such brick by longer burnings with special fluxes. The formation of tridymite is, however, comparatively slow even in

most favorable conditions, and such a process has never yet been found commercially practicable.

Immiscibility in Silicate Systems

As recently shown by Greig,* when an excess of silica is melted together with smaller amounts of many of the common metal oxides (CaO, MgO, FeO, Fe₃O₄, etc.), instead of forming a single homogeneous melt, two immiscible liquids are formed. One of these (liquid A) will be nearly pure silica and will crystallize out to form cristobalite at a temperature only slightly below the fusion temperature of pure cristobalite. The other liquid (liquid B) will freeze at a much lower temperature. The result is that over a rather wide range of compositions and temperatures, crystals of cristobalite and tridymite may be in equilibrium with a liquid phase formed by most of the common fluxing oxides. This condition exists in fields A and B in Fig. 2, which represents part of the high-silica end of the equilibrium diagram between FeO and silica. As discussed below, this effect is important in explaining the conditions in silica brick after use in an open hearth roof.

Aluminum oxide and the alkalis, however, do not give two immiscible liquids with silica, but form one homogeneous melt from which silica crystallizes at a rapidly lowering temperature as the percentage of fluxing oxide increases (up to the eutectic composition); this is illustrated in Fig. 3, which gives a portion of the high-silica end of the Al₂O₃-SiO₂ equilibrium diagram. These data indicate that alumina and the alkalis are much more dangerous fluxes for silica than most of the other oxides, and that mortars containing clay or sodium silicate should not be used in laying up or washing the surfaces of silica-brick walls or arches.

Silica Brick in the Open Hearth Roof Arch

Within perhaps 24 to 48 hours after starting up a new furnace, the inner ends of the silica roof brick have reached a maximum temperature of about 2,900 to 2,950 Deg. F. (with temperature gradients about as shown in Fig. 4 for two different arches.) This condition then prevails more or less continuously during steel making, and the hotter portions of the brick begin to recrystallize to produce the forms of silica which are most stable in the different temperature ranges, as indicated in Fig. 4. About 0.5 to 1.2 in. at the inner end of the bricks will be above 2,680 deg. F., and will soon form a stable, homogeneous structure of cristobalite crystals (with a liquid B formed by the fluxing impurities filling in the spaces between crystals). Above this zone tridymite will form more slowly by solution and recrystallization from the fluxing liquid present.

At the same time the inner roof surface is being continuously supplied with tiny particles of fluxing oxides which float up from the bath of steel and slag below. These particles average about 80 to 90 per cent of FeO and Fe₃O₄, formed largely by vapors of iron from the bath which condense to a sort of fine mist of iron oxides and are carried suspended in the furnace gases. A few per cent of MnO formed in a similar manner and fine particles of MgO and CaO make up the balance of these oxide fluxes. As already indicated, these oxides will combine with about 120 per cent of their weight of silica to give a liquid in equilibrium with the framework of cristobalite or tridymite crystals which forms the bulk of the roof brick.

*Greig, J. W., Immiscibility in Silicate Melts. Am. Jour. Sci., vol. 13, 1927, p. 143.

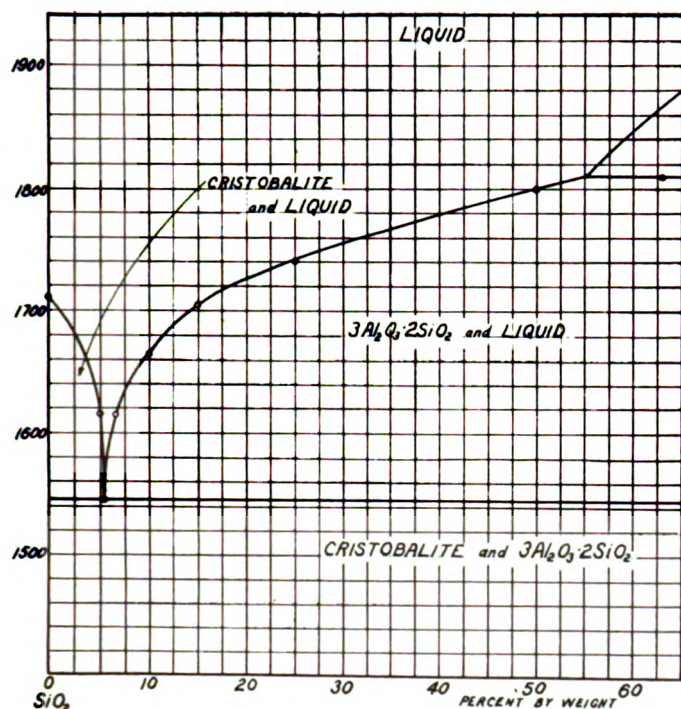
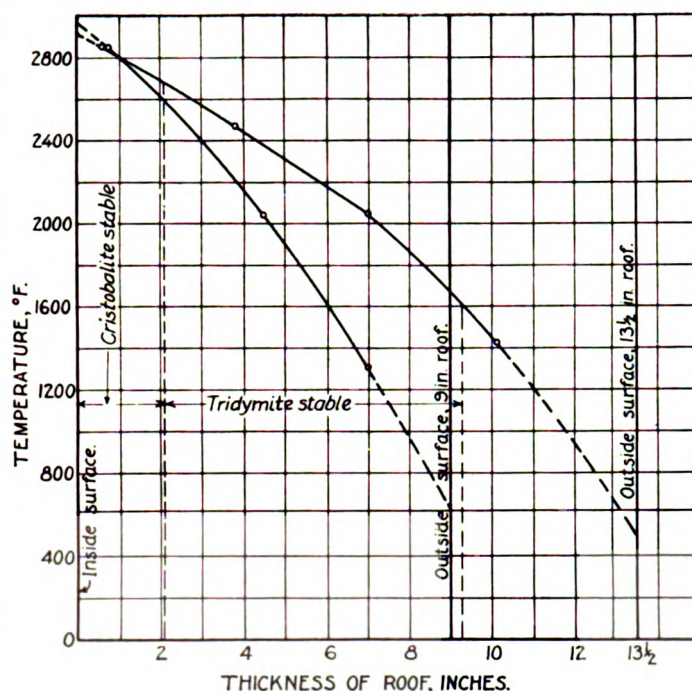


FIG. 3 (left)—A portion of the high-silica end of the $\text{Al}_2\text{O}_3\text{-SiO}_2$ equilibrium diagram. FIG. 4 (right)—Comparative temperature gradient curves for a $13\frac{1}{2}$ -in. and a 9-in. roof.



As the new brick contain about 25 per cent by volume of open pore space, they act something like sponges and soak up this liquid phase formed at their inner surface. The original silicates in the brick melt and are pushed up toward the center portions until they reach a zone cool enough to cause them to freeze, while the lower zones in the roof brick become saturated by a liquid phase formed largely by fluxes from the bath. After about a week or 10 days of steel making, this process of recrystallization and flux saturation has reached a sort of equilibrium, and if a brick is then removed from the roof a fractured cross section will appear like that of the brick shown in Fig. 5. It has a marked zonal structure, the chemical composition and melting points of the zones being about as indicated in Table 1.

TABLE I—Composition and Fusion Points of Brick from Roof of Open Hearth.

Constituent	Drips from end of brick	Zone 1	Zone 2	Zone 3	Zone 4
SiO_2	54.7*	86.3	81.9	87.0	94.6
Fe_2O_3	26.2	6.5	7.5	3.5	0.6
FeO	13.9	5.1	6.4	2.0	1.3
Al_2O_3	2.0	0.8	1.7	2.0	1.0
CaO	1.8	0.8	2.0	5.1	1.7
MgO	0.4	0.6	0.4	0.3	0.3
MnO	0.4	0.4	0.3	0.1	0.04
Total	99.4	100.5	100.2	100.0	99.5
Total Fe	29.1	8.5	10.2	4.0	1.4
Total bases	44.7	14.2	18.3	13.0	4.9
Fusion point, cone No.	Below 10	30	28	29	31
Fusion point, Deg. F.	2400-2450	3040	2970	3000	3065

*Drips from surface.

At steel making temperatures the inner end of the brick shown in Fig. 5 was a compact mass of solid cristobalite crystals with a liquid B phase filling in the pore spaces and covering the inner surface of the brick with

a thin film of liquid. As the brick are now saturated, the flux particles from the bath can no longer be soaked up and absorbed by the roof; therefore they combine with silica to increase the volume of liquid B at the inner surface. As this liquid accumulates it slowly drips off from

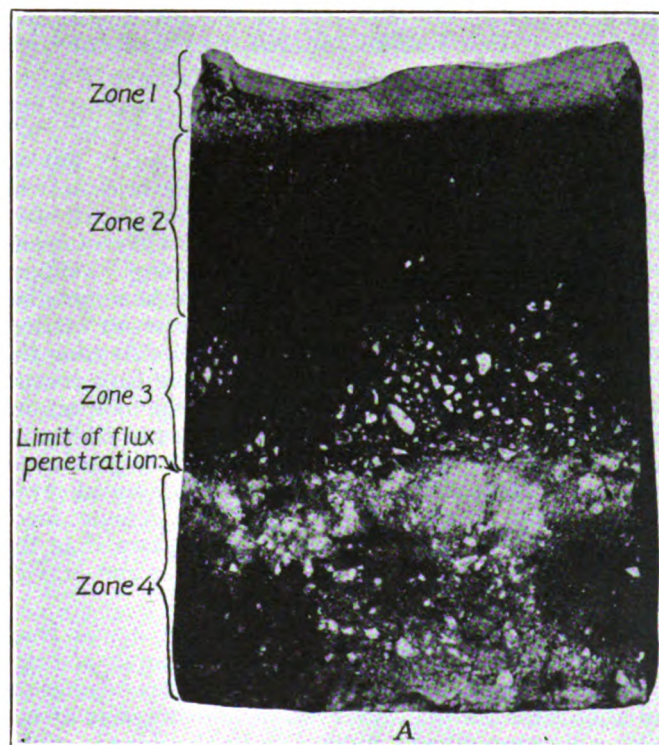


FIG. 5—Brick from open-hearth roof, after about 10 days' service.

tiny projections on the roof surface or runs down over the side walls. The drip samples given in Table 1 represents this liquid B, which in the form of little black droplets had frozen to the roof surface as the furnace cooled for

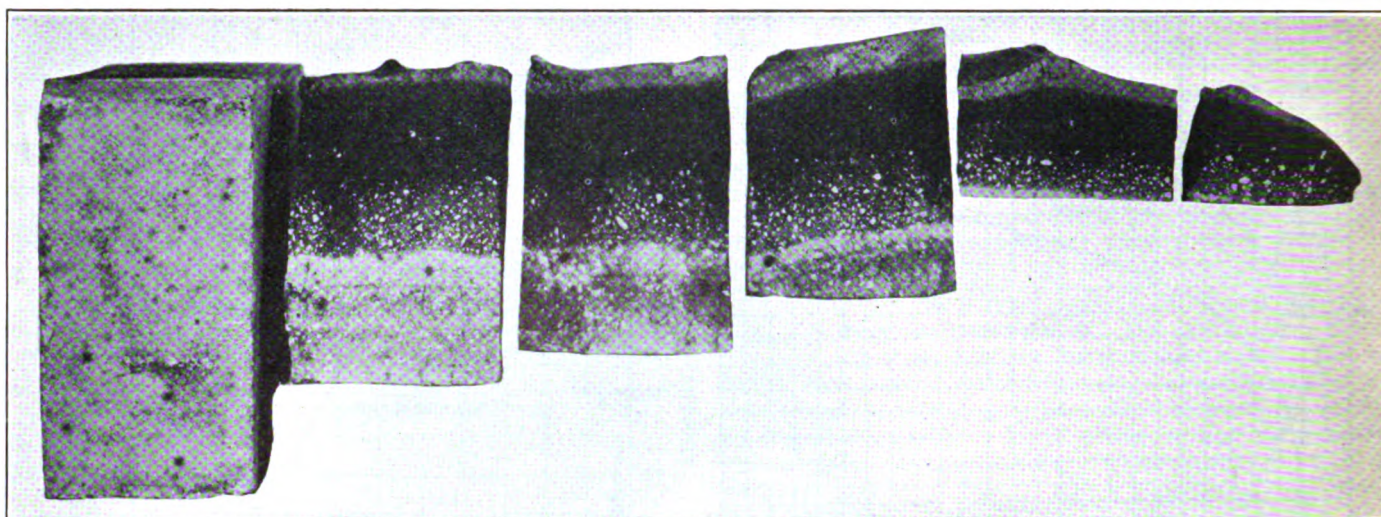


FIG. 6—Roof brick showing progressive stages of deterioration.

repairs. This liquid freezes at around 2,400 to 2,450 Deg. F. and is probably a thin, watery liquid at steel making temperatures.

Kinds of Wear or Deterioration of Roof Brick

One of the most persistent fallacies current about a silica roof is that the inner layer of the brick is in a softened or semifused state while the furnace is in operation and that the whole roof would be in danger of collapse were it not for the chilling effect of the air above the thin roof layer. Although the liquid B phase is probably very fluid at all steel making temperatures, the phase formed from the bulk of cristobalite crystals with a small amount of impurities does not melt until the range of about 2,975 to 3,050 Deg. F. is reached. It then fuses slowly to form a viscous liquid.

Fluxing and fusion are thus two distinct and separate modes of failure in the silica roof. Below 2,975 Deg. F. only the slow wearing away by surface fluxing occurs. Above this range the hot end of the brick softens bodily and forms long viscous "stringers" which drip slowly into the bath. This effect is the result of overheating and can be prevented by maintaining maximum roof temperatures below 2,975 Deg. F. The slow, gradual wear by fluxing, however, is an inevitable result of steel making conditions, because the tiny particles forming the condensed "fume" of iron oxides from the bath remain easily suspended in the gas stream, and some of them are always carried up to the roof by the haphazard eddy currents which sweep up into the colder layers of gases near the roof. These eddies can hardly be prevented, even with the best furnace design, because a definite force exists, tending to make the hotter, lighter gases from the flame zone rise up into the somewhat cooler and heavier gases near the roof.

If only scattered eddies of gases reach the roof from below, the roof heated uniformly by radiation and approximately the same amounts of oxide fluxes impinge on different areas. Often, however, definite currents of hot gases will sweep up and impinge on localized areas of the roof. These impinging currents of hot gases not only tend to overheat the roof brick in localized areas, but carry up more oxide fumes from the bath to flux away the brick. Their control is essentially a problem in furnace design, because they are caused by such things as dirty or poorly designed fuel burners, wrongly sloped or irregular port arches and wrong flame direction, too low

roof arch, scrap piled high on the hearth in the path of the flame, etc. Fig. 6 shows roof brick in progressive stages of deterioration, all taken from the same roof. The small brick on the right was adjacent to a hole actually burned through the roof, caused at least partly by a localized current of gases from the flame zone, bringing more heat and more fluxes to this area. The zonal structure is maintained while the brick wear away, and the average inner surface temperature is unchanged, but the zones become narrower as the temperature-gradient curve steepens in the thinning roof. The ideal condition is of course to have the roof surface well up out of the zone of flame and flame gases so that it is heated only by radiation and not by impinging hot gases carrying oxide fluxes. The brick then wear away slowly and evenly giving maximum life and efficiency.

If a roof arch should be well insulated, the brick would go through the same process of flux saturation and recrystallization during the first week or ten days of service. With the flatter temperature gradient, more of the brick would be heated above 2,680 Deg. F., and the inner zone composed of cristobalite crystals and liquid B would be several times thicker. If the temperature were always maintained below 2,950 to 2,975 Deg. F., such a roof should stand up as well or perhaps better than an uninsulated roof. The real danger of insulation is that a period of overheating to 3,000 Deg. F. or above would probably do more damage than with uninsulated brick (with their steeper temperature gradient and the relatively thin layer of fused material formed).

Causes of Spalling in Roof Blocks

The zone structure formed in "seasoned" brick causes two planes of weakness where the brick are liable to crack with temperature fluctuations, especially at low temperatures. Between zones 1 and 2, (see Fig. 5), a sharp transition between cristobalite below and tridymite above causes a tendency to crack along the plane dividing the two zones, probably on account of the 3 per cent volume change in cristobalite at about 450 Deg. F. Also between zones 3 and 4, (see Fig. 5) the limit of penetration by fluxes marks a sharp change from a denser, flux saturated body to the porous structure of new brick. Many brick crack through at this plane if under mechanical or thermal strain.

The greater rise in temperature and the recrystallization both cause the inner ends of the brick to expand

more than the unchanged, cooler outside zone. In order to allow for this change properly, the roof arch should theoretically become flatter as the inner zones recrystallize and expand during the first week or so of a campaign. If there is no provision for this, the arch is forced upward, spreading the outer ends of some of the brick and causing unequal distribution of pressure on the brick faces.

The ideal roof should probably be made of exactly sized brick with plane faces, and provision should be made for expansion against the skewbacks in such a way that the contacts between brick faces would be maintained during heating and seasoning of the roof. In such a roof the inner ends of the brick would remain in contact and would recrystallize together to form a continuous layer, giving nearly unbroken, glazed inner surface, almost impervious to the hot gases which tend to rise up through any openings in the arch. Uniform pressure between brick should cause less cracking and cracked pieces would be less likely to fall out, to start "holes" in the arch.

Seasoning of Roof Brick by Flux Saturation and Recrystallization

After about the first week of service, the inner ends of the roof brick are changed to fine-grained, intergrown cristobalite crystals with pore spaces filled with a thin liquid B which is in equilibrium with the cristobalite, according to field A in Fig. 2. The inner surface is covered with a thin film of this liquid which gives to the roof a surface that is a good reflector for the radiant energy re-

ceived from the flame. After this seasoning process, a roof seems to allow a more rapid heat input to the furnace without overheating. A new roof must be "eased along" for several days at the start of a campaign, to prevent overheating and "burning" of the brick. A new patch in an old roof often is badly fused while the old brick remain unharmed. Also, if spalled blocks drop out of a roof in one area, exposing unglazed inner zones to radiation, the exposed portions may be fused badly before they can become adjusted to the changed conditions.

It is difficult to explain satisfactorily the different effect of heat on old and new surfaces. It may be partly due to the protective effect of the liquid film covering the surface of a seasoned roof, more of the flame radiation being reflected and less absorbed than with new unglazed brick surface. Under certain conditions this might make possible a higher rate of heat input to the chamber with a given temperature difference between roof arch surface and the surfaces of slag or unmelted scrap on the hearth. Also, it may be important that the inner zone in a seasoned brick has come to an equilibrium state. The crystalline portion of this zone is stabilized and probably distributed in the best possible way to resist softening and slow flow of the body as a whole at temperatures near its true melting point. A new brick, on the other hand, is not yet adjusted to steel making temperatures, has a nonuniform and less perfectly intergrown crystal structure, and contains unstable tridymite and quartz with lower melting points than the stable cristobalite in the inner zone of a seasoned brick.

Refractories and the Open-Hearth

Severe Conditions of Service at Vital Points Make the Refractory Problem One Involving Not Only Material Quality but the Utmost Care on the Part of the User

By J. R. MILLER

BECAUSE of the high temperatures desirable for melting and on account of the presence of slags and oxides, the service requirements for open-hearth refractories are severe. Also when the furnace is rebuilt or repaired the pressure for time constitutes a serious drawback to accuracy and care so that often the work is not properly done. Then also, in starting out, too much stress may be laid on getting into the tonnage pace so that the proper steps are not taken to avoid damage that materially shortens the life of the furnace construction. With the difficulties that are inherent in the nature of the process and those incident to the usual plant operation the handicap to the best performance of the refractory itself is very great; and the difference between a creditable showing and a very unsatisfactory one may frequently hinge upon a small degree of difference in the carefulness by which both construction and operation are carried on. This may be a question of skill and attentiveness on the part of the operative. On the other hand it may be a question of the proper appreciation of the problems of the operative by the direct managing control.

The Roof

That the run of the furnace is determined by the life of the roof is indicative of the prime importance of this

portion of the structure. It is directly above the high temperature flame and subject to accidental impingement and to overheating. It is also subject to certain action of slags and oxides that rise up in various ways. As mostly we have to do with the sprung arch type, local erosions and injuries weaken its load carrying power and failure usually comes from local weakening. Occasionally a roof grows thin uniformly and stands up to the last, because of the uniform shape, gradually lessening weight and the cooling effect.

The newly built roof must of course be warmed up very gradually. Spalling is very destructive. If the shapes have true surfaces and the arch has been properly laid, keyed and backed up and allowance made for expansion it is not likely to spall except through abuse in heating up. If all these features have been observed the spalling becomes a question of brick quality. Unseasoned silica brick is easily fused and quickly touched up by undue temperature. Seasoning the roof inner surface at the start adds many heats to the usual run. There are two ways of doing this. The usual way is to raise the temperature maximum very slowly for about ten days operations, thus very gradually increasing the rate of production. A roof that has had this treatment very slowly becomes more and more refractory. But some operatives prefer to slowly bring the surface up to the

softening point, not so far as to cause dripping, but very nearly so, and then cool down to a degree that glazes the inside surface over. This when evenly and properly accomplished gives a very refractory condition and such a roof will stand much use and even some rather severe abuse. However it is done, the process of seasoning is most essential to a proper roof life. After that and even to the end every diligence must be practiced to be sure the fusion point is not reached at any time thereafter.

Design of the furnace plays a large part in roof life. It seems to be a fact that mostly in normal runs the roof is weakened through being eroded in a long sweep just along the back wall and seldom does a roof get thin uniformly, due to the peculiar paths of the gases or to the peculiar locations of high temperature zones or to certain slag attacks.

The Front Wall

After the roof the most serious feature affecting operations is front wall failure. If the wall is made in large blocks as is usual there is likely to be spalling and cracking on heating up for at this point particularly the doors have an influence toward rapid temperature changes so that it is hard to properly season the refractory. Here the process of seasoning must be slower. Not much can safely be done to hasten it. In fact it is wise to cover the brick as high up as practicable by spooning on a paste of chrome ore or plastering it on before lighting up. This has been known to produce a very good wall almost free from any tendency toward cracked bricks. In operation every care should be taken to protect and keep the front wall well built up on the banks, especially because the loss of the front wall means chilling the roof at the time of repair. Thus careful attention to properly building up the front wall as it is eroded will add much to the life of the roof and to the average monthly production of the furnace.

The Back Wall

It has been stated that there is not much excuse for backwall failure and when it occurs the effect on the roof life is much the same as in the case of front wall failure. There is a better chance of properly covering at all times the surface of the back wall. There is not nearly so much danger of spalling as in the case of the roof or front wall and while erosion is liable to be great at this point the remedies are more easily applied. In stationary furnaces the conditions are easier, but it is more difficult to build up the wall in routine operations. In tilting furnaces the conditions are severe and slag may easily reach the upper acid layers and even to the skew back especially in the violent reactions that are incident to certain scale and hot metal processes. But with the tilting furnace it is easier to build up by rolling back to an angle, and thus throwing on and setting the granular refractories well above the banks. Thus in the sloping back wall as applied to the stationary furnace the advantages are combined. Neutral materials are of a certain value in back wall construction on account of the exposure to slags and oxides.

High Temperature Currents

Rapid melting is of advantage in the avoidance of deflected flame from the scrap charge toward the roof, front and back. On the other hand this is accomplished by a high temperature flame which must be under absolute control, and proper rate of charging plays a part.

Here the furnace design is of great importance with reference to directional forces governing the flame path and blanket of air above. These are inherent in the neck and port design and the variety and the method of applying the fuel. Opportunities for considerable improvement over existing designs are offered the designer who studies this problem, and some definite progress has been made involving not only design, but also draft and pressure control and artificial flame control through induced forces.

The value of a proper length of flame cannot be overrated. This affects not only a saving of refractories of the ports and down takes and their bulkhead walls, but also relieving arches and the upper courses of the checker. There is a strong tendency toward too long a period of combustion in most operations, allowing flame to persist down over the outgoing end and to the lower chambers, destroying the structures of the ends and the supporting structures. Damage to ends and ports results in misdirected flame thereafter and reacts in damage to the roof and front and back walls. Fast melting and proper temperature control of the melted bath can be had by proper flame manipulation without the necessity of running too long a flame.

Joints and Air Infiltration

Poorly constructed brickwork having openings is to be avoided just as are neglected cracks caused by internal damage. If infiltration of cold air is to be avoided from the standpoint of economies, just as much is the opening to be avoided through which an outward flow of flame passes, on account damage to the refractory construction. Every open hearth operative is watchful of this and closes up such openings with rigorous care in roof or walls wherever they may be. Original construction should be made up for close tight joints properly filled with thin slurry; and much gain can be had from refractory cements, applied on the inside particularly, and here the cement gun is very efficacious.

Furnace Life and Production

It is not very profitable to make records at the early part of a run at the expense of the refractories, the long strong pull being more economical in every way. Careful attention at every step to the condition of the refractory construction means greater average production over a year's time. Rapidity in construction is desirable only where the result is satisfactory, and gains may be accomplished in material handling and proper planning. Speed of production is only possible with the furnace in good condition and defeats its own purpose in the abuse of its tools. This is particularly true of the open-hearth, where temperatures are unavoidable that are so near the capacity of the best materials.

That the qualities of refractory materials will continue to be improved there is no question. The progress of this improvement, however, must necessarily be slow. Surely, as improvement is made, it can be used to advantage only in proper designs carefully built and operated. Improvements in the design of open-hearth furnaces have been made very slowly, scarcely taking full advantage of the existing qualities of refractories or properly allowing for all the inherent weaknesses in the available materials; and much remains to be done by the designer in using the refractories to the best advantage. This is accounted for in the fact that few designers have had real operating experience and few furnace men are capable of designing or directing the designer.

Some Common Abuses of Fire Brick

Special Attention Is Directed to Two Features in Furnace Construction that Involve Unduly Severe Service—
Irregular Joints and the Keyed Arch Roof

By L. S. LONGENECKER

IF I were running for President in a realm where each fire brick had one vote, I know a platform that would draw every vote. I would not be a Wet, or a Dry, or a Democrat, or a Republican, but would choose to run as a fire brick Reformist. There are in this brick realm numerous bad conditions of long standing, which are worthy and ripe for reform. The fire bricks have borne these abuses so long that they are now in a ready mood for any reform. I would therefore seize the opportunity and win such an election on a "Reform Platform."

In this "reform platform" there would be two planks aimed at the present day abusive treatments given fire brick, and any refractory for that matter, abusive treatment of such severity that it is in most cases just downright punishment, and drives many a good fire brick down the road to a premature ruin. Millions, yes millions of fire brick hours are lost to the world each year through the general misuse of fire brick. Who pays the bill? The fire brick furnish the fodder for this needless waste, and the brick user pays the bill.

If a "reform platform," for thinner and better joints, for a full and complete investigation of the keyed sprung arch, did not sweep this fire brick election then I am ready for exile to the Isle of Brick Bats.

Thinner And Better Joints

There is much care and consideration given the matter of chemical analysis, the fusion point, the spalling test, the porosity, the kiln burn, the load test, the slag test, the reburn test, etc. These tests furnish a common "yard stick" by which to measure the true quality of a fire brick. In the manufacture of fire brick this "yard stick" is observed continually as a guide by which to produce a first quality product. In the buying of these products the same "yard stick" is referred to, in some shape or form, in an effort to secure the best brick for each particular furnace condition. Now, after both manufacturer and buyer have thus been particularly careful about the quality, they turn round and discount much of this wisdom. The manufacturer handicaps his otherwise first quality brick by allowing them to vary in thickness and to suffer in workmanship, so that they cannot be laid up with a tight thin joint. The user will very often take a first quality fire brick and install it in such haste and with such carelessness that a good service run is impossible.

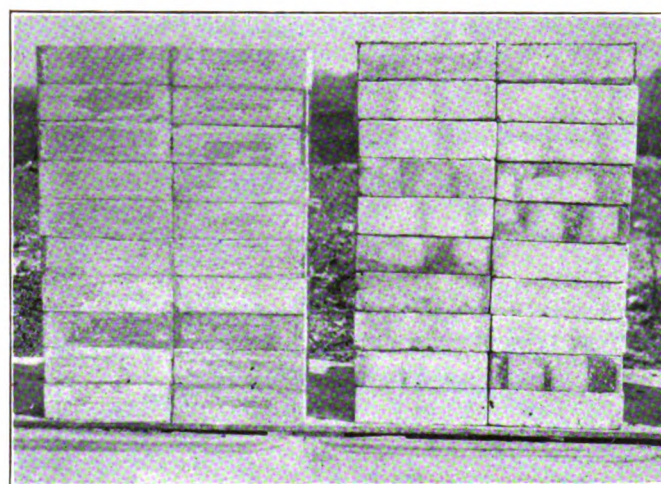
In a brick structure where the joints are irregular and large, the simple remedy is to fill them in with fire clay. This is very easily done, but after some thought it will stand out as a piece of questionable economy. The joint in most cases is the most vulnerable point of a furnace structure and generally is as weak as it is irregular and thick. An authoritative research group sometime ago made a series of measurements on the variation of sizes occurring in clay and silica brick. These tests showed in a preliminary way, that of more than 50 lots of brick tested about one half of the lots had a variation in width and thickness about 1/16 in., and anywhere up to 1/8 in. maximum. The brick measured had been made by the

following processes, dry pressed, hand made, soft mud, stiff mud, and hand and power repressed.

When a brick with an eighth in. variation in thickness is placed on a brick of the same variation a maximum joint thickness of 1/4 in. is possible. Assume that any such brick is a full 2 1/2 in. thickness. The "bed" joints or horizontal joints then will occupy about 10 per cent of the total face area, and the vertical joints will occupy another 2 per cent. This means that 13 per cent of the total wall area exposed to the high furnace temperatures is fire clay.

Fire Clay Not A Bond

Fire clay at its best is a very poor substitute for burned fire brick. When installed it is put in wet and has a marked drying shrinkage as the water passes off. In this dry state fire clay is little better than a pile of particles and dust, which has no holding strength or bonding qualities. A glazed bond is finally developed when the furnace temperature is brought up to a working point. As the furnace gases and flames move along over this brick structure the fire clay very soon freely fuses and runs out of the joints. This leaves the brick exposed and open to a flame attack from all four sides,



—By courtesy of the Chas. Taylor Sons Company.

FIG. 1 (left)—Uniform and true shape of machine edge pressed brick. FIG. 2 (right)—Stiff mud hand made brick and resulting joints.

which quickly rounds off the corners and causes brick end after brick end to slough off. Is there any question why fire brick do not give better service results when they are almost floating in semi-liquid fire clay.

Thinner and better joints will greatly reduce this wasteful abuse of fire brick. Thinner and better joints can easily be secured by installing, with care, a brick of uniform thickness and of good workmanship. A brick of these requirements is made today by various different methods. In one case it is accomplished by putting the brick through a grinding machine which buffs off all bumps that may cause variation in thickness. Another

way is to use specially designed dies and power presses. Still another method is to repress the brick on edge and in this manner the thickness of a brick is determined by the absolute dimensions of the die. The photograph of Fig. 1, shows a comparison of the joints between a stiff mud hand made brick and a machine made edge pressed brick.

A caution may well be made here lest this discussion be given the implied meaning, that a wall of no joints will be the perfect one. Note that a point of minimum thickness has been the consideration throughout; the joints in a wall have a certain service value in that they give and take the thermal expansion and contraction which cannot be ignored. They also give the wall structure that necessary degree of flexibleness which will withstand mechanical shocks such as severe jarring, shaking, twisting and bending. Thus it seems logical that the joints should be reduced to a minimum thickness and yet not be eliminated.

An Investigation of The Keyed Sprung Arch

The sprung arch "curse" has caused many a good fire brick to wake up the "morning after the night before" with a severe headache. In truth, many a good fire brick has been driven down to rack and ruin by this modern machine of torture. Picture a nice row of fine brick or shapes carefully fitted side by side and sprung between a pair of firm skewbacks where there is no allowance made for any thermal expansion. The result is that these fine brick are squeezed and pinched to pieces.

In a sprung arch the "keying" is accomplished by the use of wedge shapes, which have been suitably placed on the arch, and are pounded tightly into place. The age old argument for tight keying is that it reduces the falling out of broken tile ends, which is sad but true. This keying to offset the dropping out trouble is often so effectively done that the arch will partially spring up from

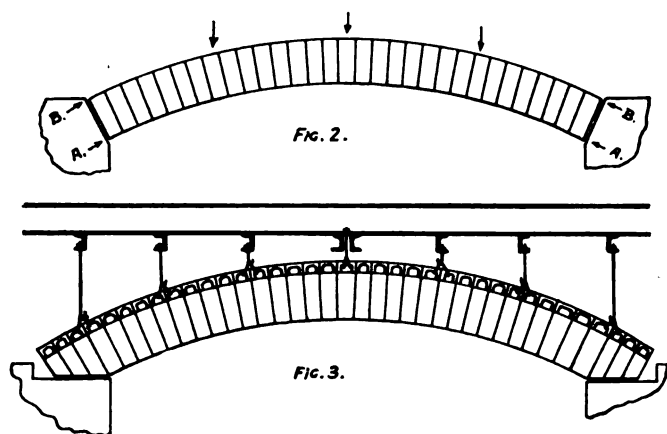


FIG. 2—A sprung arch keyed at three points as shown by arrows. The arch load is supported by the special skewbacks. FIG. 3—A radial furnace arch supported overhead showing the elimination of the skewbacks. The arch automatically allows for expansion and contraction.

the supporting center. Fig. 2 will illustrate the commonly used keyed sprung arch. In this arch each brick or shape is carefully matched up so that its complete face has a bearing contact with the next brick. Thus the sprung arch load is distributed and carried equally throughout the length of the brick. That is, the load on the inner brick ends at "A" is equal to the load on the outer brick ends at "B". So far the arch is fine and the brick have received no really harmful abuse. The trouble begins when this type is brought up to working temperatures.

In general, fire brick (clay or silica) have a thermal expansion of about $\frac{1}{4}$ in. per linear foot, and practically the whole of this expansion occurs between the temperatures of 300 deg. F. and 1,200 deg. F. Again refer to Fig. 2. The inner side of the arch A at furnace operating temperatures is well above 1,200 deg. F. and will undergo

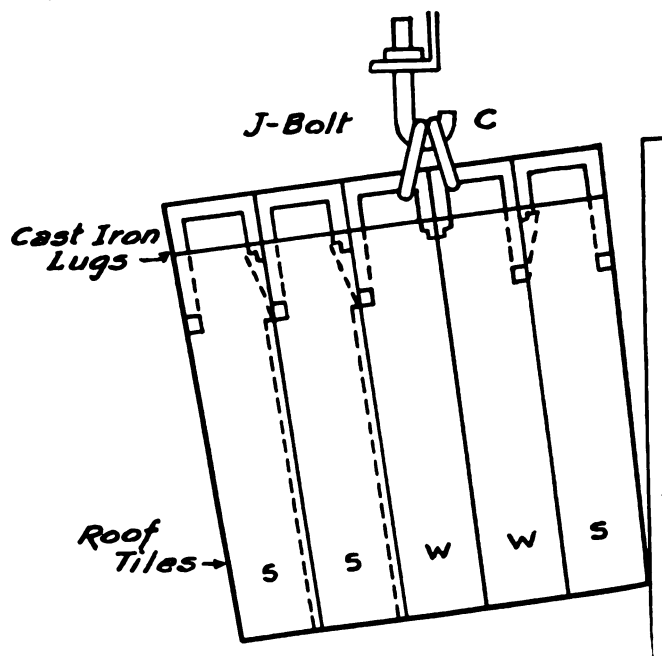


FIG. 4—The off center support of each interlocking brick and group of bricks is here shown with non-dropping out feature.

the complete thermal expansion of $\frac{1}{4}$ in. per ft. The outer side of the arch B is seldom above 300 deg. F. and will have no apparent thermal expansion. Assume that the span of this arch is 20 ft. Then the A side of the arch will have increased in length 5 in. ($20 \times \frac{1}{4}$) and since it is supported on the fixed skewbacks at AA the arch will raise up enough to allow place for this expansion. The outer side BB of the arch is now 5 in. too short, and as a result the outer brick ends will stand apart sufficiently to allow for this shortness. This behavior can be clearly seen by watching the rise of any arch as it is brought up in temperature. It is certain now that the whole sprung arch load is concentrated on the semi-soft inner brick ends.

Adjustable tie rods across the furnace are often used with the idea that they will compensate for this thermal expansion. When the tie rods are let out it permits the skewbacks to move back, which increases the span of the furnace, and this reduces the rise of the arch. This however does not grant much help as the outer arch is still 5 in. too short to make a bearing contact on the skewbacks at BB. Observe that any amount that the skewbacks are allowed to move out, in order to take up the expansion of the inner arc AA, will simply draw the outer brick contacts a like distance apart. It looks as though we are here in the same fix as the dog who has run miles and yet finds the tin can still on his tail. The tie rods have proved of very little benefit and in many cases have been discontinued for they have been of more trouble than help.

Every sprung arch, without an exception, is handicapped at the very start of a service campaign by this excessive pinching and squeezing, on the inner semi-soft brick ends. The whole arch load is concentrated and pinch-

ed on this inner side and this pressure must be excessive. After several weeks of service the arch can be noted settling down, which means the inner brick ends have been compressed and crushed enough out of shape to permit this sinking. As it settles down and the load partially shifts back into the outer cold ends, the inner sides now opens up at the joints, which give rise to an increased amount of dropping out of broken brick ends. Furthermore the brick in this crushed and spongy state are certainly not in a very strong condition to resist the erosion of the furnace gases and flames. They are very rapidly eroded away and is there any wonder that the service life of a sprung arch is less than one half of what it should be?

Supporting The Arch From Above

There is apparently no practical way of using a sprung arch without suffering this excessive pinching and squeezing. There are arches now in use which eliminate this trouble by handing the brick from overhead supports, and thus do away with the skewbacks. This permits a freedom of movement which adequately allows for all thermal expansion without binding or pinching. These suspended furnace arches are daily producing service results which show that a campaign twice that of a sprung arch is not unusual. This type arch is very rapidly finding a wider field of application. Their big use so far has been in furnace work where the brick used can be made from a non-spalling grade of clay.

Fig. 3 shows a suspended arch that is so designed that there is an automatic provision to allow for the thermal expansion. Each group of brick is supported from overhead and is hung off center as shown in Fig. 4. The overhead support at C thus serves as a pivot point around which the group can swing in order to compensate for any expansion or contraction occurring in the adjacent group. Each brick is also supported off-center which causes every brick in the arch to naturally come to rest against the adjacent brick. This combined with an interlocking brick not only eliminates all load pressures, but also secures each brick against the danger of dropping out, in whole or part.

Probably the biggest argument against the suspended arch is the matter of cost. In considering the cost of a suspended arch as compared with that of the sprung arch, it is important from the point of accuracy, that the two be placed on a proper and comparable basis. The cost of a sprung arch should include the skewbacks in place and a fair charge for the centers, as the suspended arch does not require these two items and should thus be credited with the same. The overhead steel structure should not be charged against a suspended arch unless there is a similar charge made against the sprung arch for the channel supports carrying the skewbacks. Thus, a fair and comparable basis would be, the sprung arch installed, with the skewbacks and a centering charge included, as against the suspended arch installed and composed of the brick, castings, and J-bolts. Considered on this basis the costs are very nearly even, and certainly not of sufficient difference to furnish any impressive argument in favor of the sprung arch "curse."

American Refractories Institute Meeting

The third annual meeting of the American Refractories Institute was held May 8-9 at White Sulphur Springs, W. Va. The keynote of the meeting was the consideration of the gain to be had through the fram-

ing and adoption of standardized specifications for various classes of work.

President J. M. McKinley reviewed the progress made in improvement of refractory materials and outlined plans for further betterment during the coming year. A description of the different methods used in "Screening of Fire Clays" was presented by W. W. McKee, Link Belt Company, Philadelphia. Wm. Fitzgerald, general freight agent of the Chesapeake and Ohio Railroad, covered in treating the subject of "Freight Rates on Basic Commodities" the statistics of cost in explanation of rates that are sometimes considered too high. Officers and directors were elected as follows: President, Mr. J. M. McKinley, vice president and general manager, Crescent Refractories Company, Curwensville, Pa.; first vice president, Mr. R. M. Sievers, vice president and general sales manager, Evens & Howard Fire Brick Company, St. Louis, Mo.; second vice president, Mr. W. B. Coullie, assistant general sales manager, Harbison-Walker Refractories Company, Pittsburgh, Pa.; treasurer, Mr. C. C. Edmunds, treasurer, McLain Fire Brick Company, Pittsburgh, Pa.; secretary, Miss Dorothy A. Texter, Pittsburgh, Pa. Directors, 3 year term, 1928-1931—Mr. G. A. Balz, general manager, Seaboard Refractories Company, Perth Amboy, N. J.; Mr. J. D. Ramsay, president, Elk Fire Brick Company, St. Marys, Pa.; Mr. J. E. Lewis, president, Harbison-Walker Refractories Company, Pittsburgh, Pa.; Mr. Burrows Sloan, president, General Refractories Company, Philadelphia, Pa.; Mr. A. P. Taylor, president, The Chas. Taylor Sons Co., Cincinnati, Ohio; Mr. A. P. Green, president, A. P. Green Fire Brick Company, Mexico, Mo.; Mr. H. L. Tredennick, president, Haws Refractories Company, Johnstown, Pa.; Mr. T. N. Kurtz, president, U. S. Refractories Corporation, Pittsburgh, Pa.

C. E. Bales Addresses Societies

The Michigan-Northwestern Ohio section of the American Ceramic Society, held a joint meeting with the Detroit Engineering Society on Friday evening, April 13th.

The principal speaker of the evening was Mr. C. E. Bales, production manager of the Ironton Fire Brick Company, Ironton, Ohio. The subject of Mr. Bales' talk was "The Modern Trend in the Technology of Refractories." This proved to be a most interesting subject, Mr. Bales giving a number of lantern slides showing very modern methods in the way of testing of refractories for spalling, slagging, etc.

Conference on Brick Masonry

Far-reaching improvements in one of the world's oldest industries—brick masonry were sought in a conference in New York on June 6.

Brick manufacturers, believing that the methods of utilization of their product must be perfected and inefficient methods eliminated have asked the American Engineering Standards Committee to establish a national code of good practice for brick masonry construction. Government experts, manufacturers, engineers and brick layers were present to decide whether the establishment of a national code is to be recommended at this time.

Well Known Mason Superintendents



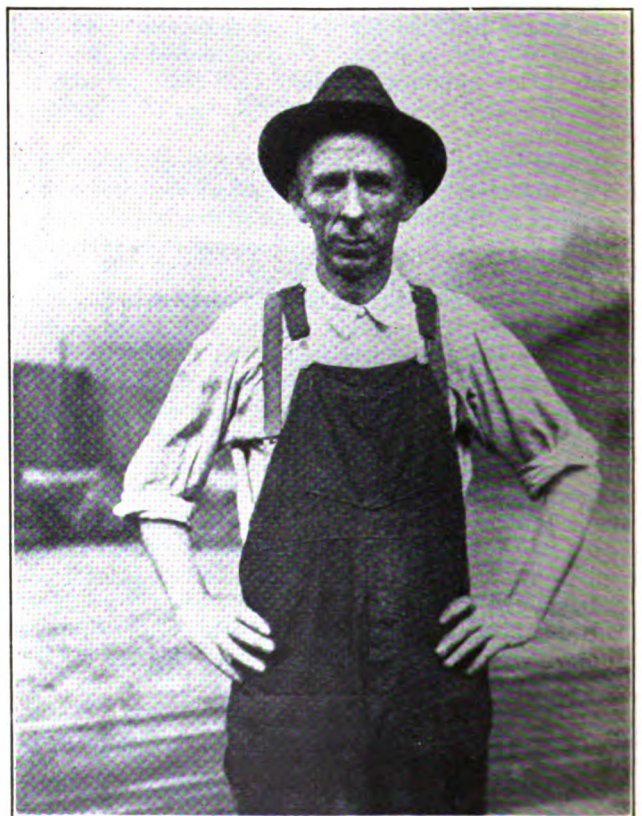
W. C. A. BUSCH
Lukens Steel Company, Coatesville, Pa.



J. H. ELLIS
Scullin Steel Company, St. Louis, Mo.



J. H. ZELLERS
American Steel Foundries, Granite City, Ill.



JOHN F. O'BRIEN
Wheeling Steel Corporation, Benwood, W. Va.

Well Known Mason Superintendents



M. J. ROWLAND
Weirton Steel Company, Weirton, W. Va.



FRANCIS D. BOTT
Carnegie Steel Company, Clairton, Pa.



ELMER JACKSON
Follansbee Brothers Company, Follansbee, W. Va.



"SAM" NAISMITH
Illinois Steel Company, South Chicago, Ill.

Kaolinic Refractories and their Properties

The Results of an Endeavor to Improve the Qualities of Refractories by Selecting Materials of High Purity and Processing to Bring Out Desirable Characteristics

By MARK J. TERMAN*

It is generally recognized that those developing refractories have been hard pressed to keep pace with the increasing demand of many industrial processes, and as a result improvements in furnace design and operation have been affected by the limitations of available materials.

In the year of 1914, The Babcock & Wilcox Company began its research and development on refractories. In the investigation of the problem the conclusion was reached that nearly all of the raw materials for refractories could be treated and processed in substantially the same manner and therefore, instead of starting with a specific raw material, it devoted the earlier years of the investigation to developing the methods and apparatus required for refractories in general.

The Raw Material

In selecting an initial material for general applications, the investigations were guided by the consideration that the majority of refractories now used are either silica or fire clay. In the case of silica, the best of the silica brick now on the market have already developed substantially the full possibilities of the raw materials. This is not equally true of fire clay brick, as the raw materials are variable, and the processes used in their manufacture are not uniform. For this reason a raw material was selected which could, by new methods, be so processed into a refractory brick that it would possess the important characteristics desired.

Among the alumina-silica materials ranging from bauxite and diaspor to the siliceous clays, the kaolinic materials are distinguished by their refractoriness, purity, stability of composition, quantity available, and uniformity of occurrence. They have not heretofore been widely used for refractories, chiefly because of the difficulties encountered in processing, although their

The material is processed by a new method which develops its refractory qualities to the fullest extent—producing a recrystallized refractory with a maximum uniformity of quality and size. Each carload of raw material is carefully tested before acceptance for processing. The possibility of deviation from standard of quality is further eliminated by rigid supervision of each process, and finally by inspection and tests of the finished product. The analysis of the material is as follows:

Silica	51.96
Iron Oxide	0.57
Titanium Oxide	1.73
Alumium Oxide	45.38
Calcium Oxide	0.10
Magnesium Oxide	0.22
Sulphur Trioxide	0.04

It will be noted from the foregoing that the material is selected for purity which results in a high melting

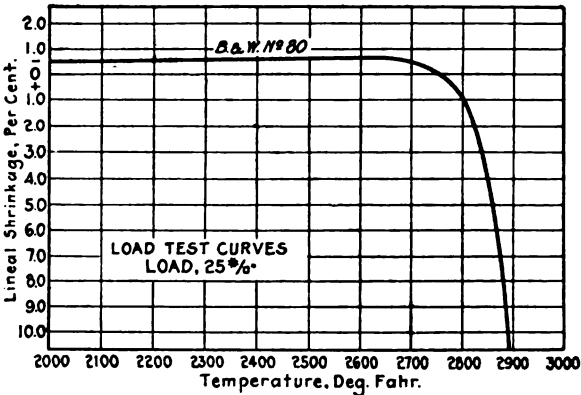


FIG. 2

point although the silica-alumina ratio is not radically different from that of certain other clays. The melting points of the resulting refractory are: 3,200 deg. F. in oxidizing atmosphere and 3,165 deg. F. in reducing atmosphere.

A study of the linear expansion curve, given in Fig. 1, will show that there is no permanent volume change in the refractory up to 2,900 deg. F. and only a slight shrinkage up to 3,000 deg. F. The average coefficient of expansion of the refractory is 0.00000242. The curve shows the expansion of the refractory to be small and that the point at which permanent volume change begins is about 2,900 deg. F. It should also be noted from the above curve that this refractory has practically a straight line expansion which explains its unusual resistance to spalling. While considering permanent volume change, it is important to note that this refractory does not "grow" under continued heat exposure and that no precautions need be taken in the designing and constructing of furnaces to allow for this.

The load test curve Fig. 2, indicates a very unusual load-bearing capacity.

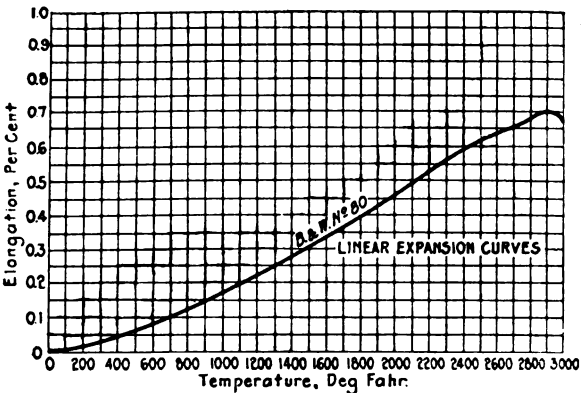


FIG. 1

potential refractory value has been recognized for many years. As a result of extensive research a kaolinic material was selected.

*Refractories Department, The Babcock & Wilcox Company, Pittsburgh, Pa.

Extensive research has established the fact that the thermal conductivity characteristics in kaolinic materials may be varied in manufacture. With reference to thermal conductivity, the application of the special materials is naturally controlled by the consideration of whether heat is to be transferred or retained in the parts of the furnace structure in which these materials are used. With its ability of withstanding loads at high temperatures and of its high fusion point, insulation may safely be used, reducing radiation losses and bettering fuel economy.

Applications of Special Refractories

This refractory has found an extensive use in many types of service including:

Steel heating and annealing furnaces.

Forging furnaces—both box-type and continuous.

Boiler furnaces—stationary and marine—fired with oil, gas, tar, wood, and coal—the latter pulverized or with stokers.

Electric resistance furnaces.

The strength of the refractory together with the close tolerances to which it can be held, makes it particularly suitable for special shapes, such as suspended arch tile, burner tile, rectangular regenerator tile, bonding tile and for many other purposes. Special shapes are made up of the same mixture and are subjected to the same heat treatment as standard shapes.

Actual performance has frequently demonstrated that the first cost of refractories is not the final consideration, and that the elimination of periodic shut-downs and increased thermal efficiencies are vital factors not to be disregarded. As a result of the growing belief that quality is an important consideration in the selection of refractories and that a reasonable factor of safety should be provided for furnace linings, the quantities of special refractories used each year are steadily increasing. In instituting the research and development work described it was assumed that there existed a definite need for refractories to meet special requirements.

Testing Refractories for the Furnace*

The Responsibility of the Manufacturer of Fire Brick and of the Purchaser in Selecting the Appropriate Brand Is Defined and Suggestions Offered

By W. BOYD MITCHELL

THE testing of a refractory for high temperature boiler furnaces is a duty devolving both on the manufacturer, to ensure that he is supplying a uniform product, and on the purchaser to ascertain relative values of competitive brands.

At Bonnybridge, where we manufacture our "Diamond" firebrick especially for boiler furnace work, our tests are made at two definite stages; on the raw material before manufacture, and on the finished product. The tests on the raw material are made entirely by examination with the microscope of powder slides. A general examination is first made to ensure that silicious, carbonaceous and other impurities have been kept out, and then by means of a travelling micrometer stage the grog content is checked and an accurate partial analysis is made. The sample is selected from the charge on the maker's bench, and, if the examination should prove unsatisfactory material, the firebricks are rejected before they reach the kiln.

Tests on Finished Bricks

Tests on the finished article are too numerous and varied to mention in detail. Any firebricks outside the size tolerance are examined to ascertain the reason. An occasional "Rattler" test checks the mechanical, abrasive resisting qualities of the firebrick. Frequent refractory and refractory underload tests and an occasional complete analysis are also of value. After-contraction tests also serve to check the uniformity of burning. Other important tests include specific gravity and porosity tests and microscopic examination.

The purchaser wishing to ascertain the relative merits of competitive brands of firebricks must also make his own tests. Many purchasers are satisfied

with comparative analyses, but this is actually insufficient, as such a test is only on the raw materials used, and ignores the methods of manufacture.

While it is important to use a high aluminous firebrick especially for powdered fuel furnaces where there is corrosion from the impinging slag, at the same time it is ridiculous to say that one firebrick, say, 2 per cent higher in alumina than another, will necessarily give better results. The firebrick with the lower alumina content may actually be more refractory and better.

To test the relative merits of several refractories the purchaser would be well advised in the first instance to satisfy himself that each of the firms offering have adopted up-to-date methods of manufacture which will ensure bulk deliveries being up to sample.

Load Tests

To compare the relative merits of the samples selected an analysis, an after-contraction test, and a refractory underload test should be made. For the refractory underload test the writer recommends the use of a load of 30 lbs. instead of the usual load of 50 lbs. per sq. inch, as in all types of boiler furnaces the load is generally a great deal less than and probably never exceeds the former figure, and it is inadvisable to ascertain and compare the relative refractory merits of firebricks under conditions differing from those to which they will actually be subjected. To put this another way, since it is the temperature and not the load which is liable to vary in the furnace, it is of more value to the user of firebricks to know his margin of safety in terms of degrees of temperature with a given load than to have this computed in terms of additional pounds per square inch which the firebricks could support at a stated temperature.

*From Engineering and Boiler House Review.

Fire Brick for Boiler Furnaces*

Tests and Investigations Advisable in Selecting a Proper
Refractory for Boiler Furnace Walls Are Outlined—
Methods for Making Up Specifications Described

By W. A. CARTER†

IN spite of the fact that a large number of boiler furnaces are being constructed with water-cooled walls, there will continue to be a large number of boiler furnaces constructed with solid refractory walls or with air-cooled refractory walls, and it is more than likely that even the furnaces with water-cooled walls will need to be supplemented with fire brick walls in order to insure satisfactory combustion conditions. For either case, a logical method must be followed in selecting the fire brick that will give satisfactory service.

A logical method to use in selecting a fire brick is to consider the physical properties that it should possess, the results of certain laboratory tests upon various brands of brick, including if possible, those used in actual service conditions under consideration. Even then, before finally adopting a brick by this procedure it should be given a thorough set of service tests.

The physical properties that should be given consideration are resistance to slag erosion, resistance to temperature shock spalling, fusion temperature,‡ deformation under load while hot, uniformity of size, thermal expansion, constancy of volume upon repeated heating and cooling, freedom from laminations, and last, but not least, uniformity of composition and firing.

Present day specifications and laboratory tests for fire brick for this kind of service are helpful in some respects but are inadequate in others. The standard test for fusion‡ temperature is reliable, but it gives the fusion‡ temperature of the brick for only one set of gas conditions, whereas the brick in service may be exposed to either oxidizing or reducing gases. The brick would fuse at a lower temperature under the latter conditions. The average uniformity of size can be measured on stacks of ten bricks. Thermal expansion can be accurately measured in the laboratory. The constancy of volume test§ is a good criterion of the perfection of firing in the kiln. The present tests for resistance to slag erosion are far from satisfactory, and in most cases give erroneous indications of the results obtained in service. A satisfactory test must simulate service conditions as to brick temperature, slag composition and viscosity, and furnace atmosphere. One investigator is developing such a test. The water-dip spalling test subjects the brick to far different conditions than those in boiler furnaces. It appears that the development of the spalling test that is being made by the American Refractories Institute will result in a much more satisfactory test. The standard load test of fire brick while hot does not duplicate service conditions as the brick is heated uniformly throughout, whereas in service there is usually a steep temperature gradient from the hot to the cool faces.

*Abstract of a paper from the American Refractories Institute, Technical Bulletin 22.

†Technical engineer of power plants, The Detroit Edison Company.

‡Pyrometric Cone Equivalent (P. C. E.)

§Careful interpretation of the test data is necessary, especially in the case of brick made of Pennsylvania clays which exhibit secondary expansion.

Generally the manufacturers will be glad to furnish Mellon Institute data on their brands of brick that will show the laboratory results of tests on fusion* temperatures, constancy of volume, deformation under load while hot, and spalling by either the water-dip or the tentative air blast tests. An alternate scheme would be for the brick user to have samples of the various brands of bricks tested in an adequately equipped ceramic laboratory. For any particular test all of the brands should be tested in the same laboratory to avoid errors due to difference in laboratory methods. A comparison of these data for the various brands will indicate, with a certain degree of reliability, the brand or brands that appear to have the best combination of physical properties for use in boiler furnaces.

The service tests are more valuable to both the user and the manufacturer if a well informed service man follows with the user the performance of the brick. Too often the brick manufacturer does not acquaint himself with the actual service conditions.

After selecting the brand, or brands, of bricks giving satisfactory results in the service tests the user should draw up from the laboratory tests and elsewhere a workable specification upon such of the physical properties as he can, including fusion* temperature, deformation under load while hot, dimensional tolerances, constancy of volume upon repeated heating and cooling, freedom from blemishes, defective corners and cracks, etc. The manufacturer should be given a part of one of his bricks that survived the service tests, the user keeping the other, these to serve as a guide for the texture and the fineness of grind desired. The specifications and brick sample should be used when inspecting shipments to insure getting bricks like those originally used in the service tests.

Adequate attention should be given to the storing and handling of the bricks after they are unloaded at the boiler plant. Many good bricks are badly damaged by neglecting these matters.

The user should keep accurate service records and study the brick failures. A careful analysis may point out construction features that should be changed. Among the common construction faults are insufficient allowance for expansion of the brick, poor joints which are attacked by slag, and difficulty of replacing sections of the furnace walls that have failed, without disturbing that part of the wall immediately above. The fault of allowing insufficient space for expansion is corrected by experience. The fault of poor joints can be corrected by laying the bricks with rubbed, or face to face joints and using in the joints a "filler" of calcined and raw clays of refractoriness equal to that of the clays used in making the brick. There should be enough calcined material in the filler to prevent shrinkage, and both the calcined and raw clays should be ground fine enough to make it workable as a slurry. Providing easy means of making replacements in the furnace walls requires special considerations peculiar to each type of furnace.

*P. C. E.

INFORMATION FOR THE MASON

Working Temperatures

By M. C. Booze*

Blast furnace tuyeres.....	3150 deg. F.
Blast furnace tapping.....	{ Slag 2650 to 2750 deg. F.
	{ Metal 2625 to 2700 deg. F.
Open hearth furnace during boil.....	3100 deg. F.
Medium hard steel at tapping....	2800 to 2900 deg. F.
Gas leaving producers.....	1000 to 1200 deg. F.
Gas leaving regenerators.....	1600 deg. F.
Air leaving regenerators.....	2000 deg. F.
Waste gas at stack.....	1000 to 1500 deg. F.
Steel ready to roll.....	{ High sulphur 2300 deg. F.
	{ Soft steel 2200 deg. F.
	{ Spring steel 2000 deg. F.
Crucible steel furnace.....	2650 deg. F.
Rotary cement kiln on clinkering.....	2850 deg. F.
Shale drain tile burning.....	1900 deg. F.
Fire clay stoneware burning.....	2200 deg. F.
Fire clay sewer pipe—hottest.....	2200 deg. F.
Shale sewer pipe.....	2000 deg. F.
Fire clay paving brick.....	2100 to 2200 deg. F.
Shale paving brick.....	2000 to 2100 deg. F.
Under a boiler. { Stoker fired	Up to 2800 deg. F.
	{ Powdered coal fired Up to 3050 deg. F.

Heating Furnace

The temperature obtained was for a 24-in. ingot being heated for forging. Back wall temperature, maximum 2500 deg. F. The temperature for smaller stock will vary according to the size and shape of the piece being heated, but the average within the heating furnace is approximately 2500 deg. F. for rolling. Where stock is being heated for welding, the temperature will be 200 or 300 deg. higher than this.

Electric Furnace for Steel Melting

Steel is ordinarily supposed to be tapped from an electric furnace at a temperature about 50 deg. higher than from an open hearth furnace. However, some actual comparative ratings gave temperatures between 2850 and 2950 deg. F. for an electric furnace making ordinary steel.

Glass Pots Working

Temperature will vary between 2200 and 2700 deg. F., depending upon the kind of glass being melted. A fair average would probably be 2600 deg. F.

—Bulletin of Crescent Refractories Company.

*Senior fellow, Refractories Manufacturers Association Fellowship.

Useful Information

Fire brick should be kept dry.

Approximately 500 pounds of fire clay will make mortar enough for 1,000 brick. If you can keep it down to 400 lbs., so much the better.

In laying fire brick the thinnest joint possible should be used. Let the mortar be a thick, soup-like

mixture so it will pour from a dipper. Dip the bonding surface of the brick and rub or hammer them together. Close, tight joints will prove real economy and lengthen the life of the brick.

Do not add any foreign materials to dry-milled fire clay used for mortar. Under no circumstances should any mixture of Portland cement, lime, asbestos or salt be used in the mortar.

After your fire-brick work is done the furnace should be slowly heated to expel all the moisture. Don't put furnace on high fire until the brick work is entirely dry.

For estimating the number of brick required for a certain piece of work, use the following figures: 1 sq. ft. 4½-in. wall requires 7 brick; 1 sq. ft. 9-in. wall requires 14 brick; 1 sq. ft. 13½-in. wall requires 21 brick; 1 cu. ft. of brick work requires 17 9-in. straight brick.

Approximately 8,500 fire brick will make a minimum car load, 60,000 lbs. capacity car.

One cu. ft. fire clay brick weighs approximately 140 lbs.

1,000 brick, closely stacked, occupy 56 cu. ft.

1,000 brick, loosely stacked, occupy 72 cu. ft.

—A. P. Green Fire Brick Company catalog.

The A-B-C's of Fire Brick

Question—What is clay?

*Answer—*Clay is a natural mineral substance, embracing all of the alumina silicates which will absorb water, and after reduction, will retain their molded form when dried.

Q.—What is fire clay?

*A.—*Fire clay is any clay which will stand without deformation the common high temperatures in the mechanical arts. Strictly speaking, the fusion point of fire clay must exceed Cone 27. High grade fire clay is a double silicate of alumina, composed of the hydrous silicate of alumina combined with silicates of certain other minerals.

Q.—How does fire clay occur?

*A.—*It is usually associated with bituminous coal measures, and lies in veins in the same manner as coal. These are primary deposits. Secondary deposits occur when the original measure has been washed into a new level. With but few exceptions, the truly high grade clays are primary.

Q.—How is fire clay mined?

*A.—*In the same manner as coal, by drift, slope, or shaft development. In some localities, it is obtained by stripping off the over-burden.

Q.—What types of fire clay are used in the mechanical arts?

*A.—*Flint, semi-flint and plastic.

Q.—Wherein does hard or flint clay differ from plastic or soft clay?

A.—Flint clays are dense and tough, have a waxy luster and break with a conchoidal fracture. They are highly refractory (Cone 33 plus), constant in volume over a wide range of temperature, and practically non-plastic when reduced. Plastic clays are generally sedimentary in origin, containing a higher percentage of silica, and higher impurities, and consequently having a lower fusion point than flint clays. They possess marked plasticity when ground, and are available as bond material when reasonably constant in volume, under fire.

Q.—How are these clays varied in combination to produce various refractory brick?

A.—The two grades of clay are mixed with the service factor in mind. For high temperature resistance and moderate physical strength the content of flint clay is increased. For moderate temperature duty combined with abrasion, the plastic content is usually increased. A large variety of combinations is possible.

Q.—How are these clays treated mechanically?

A.—Mined, crushed, ground and tempered, molded, pressed, dried and burned.

Q.—What is the hand made process?

A.—The clays are reduced by crushing and grinding in a wet pan. The molding is done by hand, after which the rough brick are off-borne for tempering on a hot floor; after tempering they are pressed by hand, dried for about 96 hours on a hot floor, and then set in the kilns for burning.

Q.—What is the stiff mud process?

A.—The clay is first crushed, and then reduced by a dry pan and screens, or by wet pan only, after which it is fed to a pug mill, and through an extrusion machine forming the rough brick, which are repressed mechanically or by hand, dried and burned.

Q.—What is the dry press process?

A.—After crushing the clay is reduced in a dry pan and screened. A mixing mill is employed, feeding to a heavy multiple press where the semi-moist material is formed in one operation, after which it is dried and burned.

Q.—What other processes are available?

A.—The above basic processes are now clearly defined. The hand made process is modified occasionally by mechanical molding devices followed by hand repressing. Direct extrusion without repressing may be employed.

—Bulletin of Crescent Refractories Company.

Table for Circular Brickwork

Method for determining a suitable combination of arch, wedge or key brick to turn a given circle.

Formula:

$$A \div C = E$$

$$B \div E = D$$

$$E \times (D-G) \div (F-G) = L$$

$$E \times (F-D) \div (F-G) = S$$

A—Outside circumference of brick circle.

B—Inside circumference of brick circle.

C—Width of standard brick at butt.

D—Width of theoretical brick at point.

E—Total number of brick in circle.

F—Actual width of brick nearest but greater than D at point.

G—Actual width of brick nearest but less than D at point.

L—Quantity of largest size brick required.

S—Quantity of smallest size brick required.

—The Improved Equipment Company.

News Items in the Refractory Industry

At a meeting of stockholders of the Harbison-Walker Refractories Company, directors were named as follows: James Dilworth, of the Dilworth-Porter Company, representing the interests of the Mississippi Glass Company and the Walsh Fireclay Company; A. B. Clements, representing interests of the American Arch Company; S. C. Brookes, Jr., representing interests of the Continental Share Company, and Richard K. Mellon.

* * *

J. B. Arthur of the A. P. Green Fire Brick Company, Mexico, Mo., won the golf championship of the American Refractories Institute at its annual meeting at White Sulphur Springs, W. Va. H. B. Plunkett who also attended from the A. P. Green Company, finished among the first ten in the tournament.

* * *

Prof. George A. Bole, of the Department of Ceramic Engineering, Ohio State University, in carrying out the campaign to acquaint the people of Ohio with its many industries, gave a half-hour talk over Station WEAO at Ohio State University on the ceramic industry in Ohio.

Prof. Bole told of the great resources in clays and shale that are found in Ohio. He also described the ceramic industry in that state, giving figures as to the extent of the ceramic products made and exported to foreign countries.

* * *

Officers elected for Ashland, (Ky.) Fire Brick Company, include E. H. Gærtrell, president and general manager; John Russell, vice president; E. M. Wein-furtner, secretary and treasurer.

* * *

The Missouri Clay Testing and Research Laboratories at Rolla, Mo., which is operated under the direction of the Ceramic Engineering Department, Missouri School of Mines, has made steady progress during the past year, the average amount of work now being about seven times that of a year ago.

* * *

J. L. McLain has been appointed western sales representative of the McLain Fire Brick Company. He will have headquarters in Chicago.

* * *

Dr. R. P. Heuer is resigning as instructor in Chemical Engineering at the University of Pennsylvania to become director of research for the General Refractories Company. He will make his headquarters at the general offices of the company in Philadelphia.

In addition to directing the company's research laboratories at Baltimore, Md. works, Dr. Heuer will devote much of his time to field work among refractories users on technical problems related to the company's general products and specialties.

* * *

A. P. Green, president, A. P. Green Fire Brick Company, Mexico, Mex., has recently returned from a trip abroad, after an absence of about two months.

TRADE NOTES

Recent orders received by the Sutton Engineering Company include the following: One wide hot strip leveller and two wide cold strip levellers for the Trumbull Steel Company; one wide cold strip leveller for the Weirton Steel Company; one copper sheet leveller for the Taunton-New Bedford Copper Company; one fast cold drawn bar straightener for the Bethlehem Steel Company; two small cold drawn bar straighteners and two high speed large cold drawn bar straighteners for the Union Drawn Steel Company; one special high speed seamless tube straightener for the Jones & Laughlin Steel Corporation; one large seamless tube straightener for the Pittsburgh Products Company; one top and bottom roll type straightener for automobile door and other sections for the Columbia Steel & Shafting Company; one fast butt-weld pipe straightener for Clayton Mark & Company; one fast bar straightener for the Pittsburgh Crucible Steel Company; one fast aeroplane tube straightener for the Summerill Tubing Company and equipment for the Canadian Tube & Steel Products, Montreal, Can.

* * *

The Mesta Machine Company have placed a contract with The Rust Engineering Company of Pittsburgh, Pa., for the construction of a continuous furnace to be installed in conjunction with the continuous mill which they are building for the Timken Roller Bearing Company, Canton, Ohio.

The furnace is to be equipped with Rust refractory tile recuperator and will have an output of 50 gross tons of billets per hour. The size billets to be heated will vary from 2 by 2 in. to 5 by 5 in. and will be 30 ft. in length. The heating hearth of the furnace will be 55 ft. wide by 51 ft. in length. To give this high tonnage, billets will be charged in the side, pushed throughout the length of the heating hearth and discharged from the opposite side of the furnace directly into the first stand of the continuous mill. The fuel to be used on this furnace will be natural gas and a very low consumption will be obtained due to the highly preheated air delivered by the recuperator.

Since this furnace will heat alloy billets, great care has been taken to reduce scaling losses to a minimum. To aid in scale reduction as well as to obtain easy operating conditions for the heaters, combustion control and draft regulation equipment as made by the American Heat Economy Bureau will be used on this furnace.

* * *

The Newton Steel Company have placed a contract with The Rust Engineering Company of Pittsburgh, covering the construction of a pack heating furnace for use with their sheet mills at Newton Falls, Ohio. This pack furnace will be the first of its kind for heating sheets and will have an output of 30 tons of sheets per 8 hour shift. It will be 5 ft. wide inside and approximately 47 ft. in length. The sheet pack will be carried through the furnace on Kathner type disc rolls as made by the Duraloy Company. Producer gas will be used as fuel. In conjunction with this furnace a recuperator will be installed to supply preheated air for combustion.

* * *

Announcement is made by The Wellman-Seaver-Morgan Company, Cleveland, Ohio, of the appointment of the following sales distributors for the marketing of their

recently developed line of Wellman Supertest Gate and Globe Valves which are designed for the most exacting requirements that can be imposed by the highest pressures and temperatures in modern steam plants, oil refineries, pipe lines, hydraulic, air, gas, chemical service and other industrial purposes: Acme Well Supply Company, 136 Liberty Street, New York; Basil S. Burgess, Coal Exchange Building, Huntington, W. Va.; Eastern Steam Specialty Company, 270 Lafayette Street, New York; Walter G. Heacock, Detroit, Mich.; Steam Equipment Manufacturing Company, Pittsburgh, Pa. and R. George Ward, 809 Harrison Building, Philadelphia, Pa.

* * *

The Celoron Company, (Division of the Diamond State Fibre Company), Bridgeport, Pa., in conjunction with the opening of its new laboratory, and the introduction to the electrical, radio and automotive fields of Celoron molding compounds, announces the appointment of Mr. R. W. Wales as factory representative on molding powders and resins. Mr. R. W. Wales enjoys a background of many years of experience in the developing and manufacture of molding compounds, having been connected with one of the largest manufacturers of this material for 15 years.

* * *

It is announced that the Ingersoll-Rand Drill Company with offices at 314 N. Broadway, St. Louis, Mo., was succeeded by Ingersoll-Rand, Inc., on May 1, 1928. A new branch operating under the St. Louis office has just been opened at 226 West A Street, Picher, Okla. It is felt that by establishing this new office the Company will be in a better position to serve its customers in northern Oklahoma, southern Missouri, and Arkansas.

* * *

Through stock ownership in the Hamilton By-Product Coke Ovens, Ltd., and the United Gas and Fuel Company, Ltd., also of Hamilton, control of these two well known Canadian companies is now vested in United Fuel Investments, Ltd., according to announcements made by the latter organization through A. T. Leavitt, managing director.

The United Gas & Fuel Company, with its predecessor company, has been delivering gas in the city of Hamilton for more than 60 years. It owns one of the largest single gas holders in the Dominion of Canada, with a capacity of 6,000,000 ft., which distributes gas through 500 miles of mains for commercial and domestic purposes. The Company owns a modern by-product coke oven plant, having a carbonizing capacity of 1,000 tons of coal per day.

Under the new direction, further important extensions are under advisement to meet a growing demand for domestic coke made at the Hamilton plant.

The new directors of the Hamilton By-Product Coke Ovens consist of: Norman S. Braden, Vice President of the Canadian Westinghouse Company; Alan V. Youngs, President of the Hamilton Cotton Company, Ltd.; J. P. Bell, Canadian Bank of Commerce; J. A. Fraser, Vice President of the Dominion Securities Corp. of Toronto; W. H. Lovering, and John T. Byrnes.

* * *

The Westinghouse Company has recently sold through the Ingersoll-Rand Company a 2,000 h.p., 3,600 r.p.m. 4,800 volt 3 phase, 60 cycle, 100 per cent power factor, synchronous motor of the turbo type to drive a 40,000 cu. ft. gas booster blower to be located in the 110th and Torrence Avenue plant of the Peoples Gas, Light & Coke Company, Chicago.

NEWS OF THE PLANTS

The American Rolling Mill Company has started upon a program of improvement at its Butler, Pa., works, which includes annealing, pickling and cold finishing equipment. The operations contemplated will be modeled after those at the Ashland, Ky., works.

* * *

The Empire Steel Corporation has announced the completion of its new galvanizing plant at Niles, Ohio. The new unit formerly was the plant of the Falcon Steel Company. Three galvanizing pots have been installed, the equipment being designed to take sheets of all gages and up to 50 in. in width.

* * *

The Otis Steel Company took the first heat from its new 150-ton open-hearth furnace on May 15. The furnace was completed in record time, ground having been broken for construction February 13.

* * *

The Weirton Steel Company of Weirton, W. Va., will build an additional 250-ton open-hearth furnace with producers. This will make a total of 12 furnaces. Additions will be made to the pit furnaces, strippers, slab yard and to the 10-in. and 16-in. mills. The work of construction is to start immediately.

* * *

The House River and Harbors Committee has reached the decision to recommend a 24-ft. depth at connecting channels on the Great Lakes, an increase of 3 ft. over the present nominal depth. This, if ratified by Congress, will mean a considerable increase in the cargo of lake freighters and will be of particular advantage to the ore carriers.

* * *

The Paterson-Leitch Company of Cleveland, Ohio, has recently completed an addition to its warehouse at 400 East Sixty-ninth Street.

* * *

The Fort Wayne Rolling Mill Corporation, Fort Wayne, Ind., has been purchased by Joslyn Manufacturing and Supply Company, Chicago. The Fort Wayne concern manufactures iron and steel bars, bands and small angles, channels and shapes.

* * *

Work of dismantling No. 4 blast furnace of the Rodgers-Browne group, Buffalo, now owned by the M. O. Hanna Company, is nearly completed. The furnace will be replaced by a new stack of larger dimensions which, it is planned, will be producing early in October. The rated production is set at 600 tons per day. The present blowing engines and stoves will be retained. The M. A. Hanna Company now has seven stacks in Buffalo.

* * *

The General Pressed Steel Company, composed largely of Newton Falls investors, has been formed by Harry Schaab, formerly sales manager of the Commercial Shearing & Stamping Company of Youngstown, Ohio. The company is erecting at Newton Falls a factory for the manufacture of stamped steel prod-

ucts, near the plant of the Ohio Structural Steel Company. Mr. Schaab will be general manager and sales manager of the new concern, whose other officers are: President, M. H. Stauffer; secretary, Howard Booher and treasurer, Reese Jones.

* * *

The Canadian Furnace Company, Ltd., lit up its Victoria Furnace May 24. This is Queen Victoria's day in Canada. The Canadian Company thus returns actively to the Canadian pig iron market following the modernization of its furnace and Welland Canal improvements effecting the company's ore dock. Sales offices are located at Hamilton, Ont. George A. Simpson is sales manager.

* * *

The Bethlehem Steel Company has increased its line of wide structural shapes adding a series of 33-in. beams and girders. These are said to be the deepest sections ever rolled in this country. The beams are produced in four weights from 125 to 152 lbs. per ft. with section moduli respectively from 394.3 to 478.4. The girders are rolled in four weights from 202 to 230 lbs. per ft. section moduli, 676.0 to 778.0 respectively. In the design of these sections arrangements are made to give maximum strength per pound of material. The contour is similar to that of the other Bethlehem sections.

COMING MEETINGS

June 4-7—Sheet Steel Executives sixth annual meeting. White Sulphur Springs, W. Va.

* * *

June 8-12—American Gas Association, Annual Meeting, Atlantic City, N. J. Alexander Forward, managing director, 420 Lexington Avenue, New York.

* * *

June 14-16—American Society of Mechanical Engineers, National Oil and Gas Power meeting, Pennsylvania State College, State College, Pa. Calvin W. Rice, secretary, 29 W. Thirty-ninth Street, New York City.

* * *

June 25-29—American Society for Testing Materials. Annual meeting at the Chalfonte-Hadden Hall, Atlantic City, N. J. C. L. Warwick, secretary, 1315 Spruce Street, Philadelphia, Pa.

* * *

June 25-29—Association of Iron and Steel Electrical Engineers. Annual convention and exposition at Hotel Stevens, Chicago. John F. Kelly, 705 Empire Building, Pittsburgh, is secretary.

* * *

Sept. 17-20.—American Society of Mechanical Engineers, Second National Fuels meeting at Cleveland, O., Calvin W. Rice, secretary, 29 W. Thirty-ninth Street, New York.



J. A. Carrington, former superintendent of the Trumbull Steel Company tin house, resigned on May 1 to accept a similar position with the Bethlehem Steel Company at Sparrows Point, Md.

* * *

C. H. Heist has been appointed blast furnace superintendent of all properties of the Youngstown Sheet & Tube Company, succeeding R. S. Braman. Mr. Heist formerly was superintendent of blast furnaces at Mayville, Wis.

* * *

L. F. Quigg, superintendent of the Franklin plant of the Bethlehem Steel Company, has resigned to become general superintendent of the Minnequa Works of the Colorado Fuel & Iron Company at Pueblo, Col. He will be succeeded by F. E. Howells, formerly of the Bethlehem plants at Lackawanna and Steelton, Pa. E. W. Trexler will take Howell's place as superintendent of the Franklin mechanical plant.

* * *

C. F. W. Rys, in charge of the metallurgical department of Carnegie Steel Company, has been appointed assistant to the president. He will continue to be metallurgical engineer of the company. He joined the Carnegie company in 1904. He is a member of both the American and the British Iron and Steel Institutes. Rys was born in Essen, Germany, and is a graduate of the school of mines at Freiberg, in Saxony.

* * *

Robert W. Keeney, who for five years has been general superintendent at Midland, Pa., for the Pittsburgh Crucible Steel Company, Pittsburgh, has been elected president of the company. Mr. Keeney has been identified with the steel industry in operations for 20 years having been successively connected with the Illinois Steel Company at South Chicago, the New York State Steel Company at Buffalo (now the Donner Steel Company), the Jones & Laughlin Steel Corporation at its Alliquippa Works, the Whittaker Glessner Company, Portsmouth, Ohio, and the Central Iron and Steel Company at Harrisburg, Pa.

A. L. Sonnhalter, assistant general superintendent of the Midland plant of the Pittsburgh Crucible Steel Company, has been made general superintendent, succeeding R. M. Keeney.

* * *

J. T. MacKenzie, American Cast Iron Pipe Company, Birmingham, Ala., will address the members of the Quad City Foundrymen's Association at a meeting on May 21.

* * *

Alfred E. Munch, Jr., has been named Chicago-Milwaukee representative of the Rollway Bearing Company, Inc., Syracuse, N. Y., with headquarters in the Railway Exchange Building, Chicago.

* * *

E. J. Lowry, formerly metallurgist with Hickman, Williams & Company, has resigned and plans to serve the iron and steel industry as general consultant. His office is 2-164 General Motors Building. Mr. Lowry is author of a number of papers on pig iron and blast furnace practice.

* * *

Charles T. Johnston has resigned as Pittsburgh district sales agent for the Republic Iron & Steel Company, Youngstown, Ohio. Mr. Johnston was connected with the sales department of the Republic company for many years, having been district sales agent at Cleveland and later, general sales manager at Youngstown.

* * *

Harry E. Kies, executive manager, malleable iron department, American Radiator Company, Buffalo, in addition to his duties has been given also the management of the steel department, succeeding E. Phelps Longworthy.

* * *

The appointment of C. W. Stone, manager of the General Electric Central Station Department, to the position of consulting engineer, and the selection of M. O. Troy as manager of the Central Station Department, have been announced by President Gerard Swope of that company.



R. M. Gibbs has been appointed advertising manager of the Pittsburgh-Des Moines Steel Company, Pittsburgh.

* * *

S. J. Cort, superintendent of the Saucon plant of the Bethlehem Steel Company, has been appointed assistant general manager of the Maryland plant. E. F. Entwisle, assistant general manager of the Steelton plant, will succeed Mr. Cort as superintendent of the Saucon plant. R. B. Gerhardt, assistant general manager of the Maryland plant, has been appointed assistant general manager of the Steelton plant.

* * *

Kenneth J. Burns has been appointed district sales agent for the Youngstown Sheet & Tube Company, in charge of the Youngstown, Ohio, district sales office. He has succeeded Myron S. Curtis who has resigned to enter another line of business. Mr. Burns formerly was in the Cleveland sales office of the Youngstown company.

* * *

Henry C. McEldowney, president of the Union Savings Bank and the Union Trust Company, both of Pittsburgh, was elected a director of the General Electric Company at an organization meeting of the board held in Schenectady May 8. The stockholders, at their annual meeting held that morning, authorized the additional director, increasing the total from 20 to 21. Other directors were re-elected. Mr. McEldowney is a director of the Mellon National Bank of Pittsburgh and of the Pittsburgh Chamber of Commerce.

* * *

Hans. J. Meyer has been appointed an engineer of the Foreign Department of International Combustion Engineering Corporation. Mr. Meyer will sail June 6 for the Far East.

Mr. Meyer has had extensive experience as an engineer and executive, having been district engineer, Allis Chalmers Company; sales engineer, Westinghouse Electric & Mfg. Company; superintendent, Shreveport Gas, Electric Light & Power Company, Shreveport, La.; partner in the consulting engineering

firm of Vaughn, Meyer & Sweet, Milwaukee; and partner with Charles L. Pillsbury and F. A. Vaughn in the consulting engineering firm of Charles L. Pillsbury Company, Minneapolis and St. Paul. During the war, Mr. Meyer was appointed administrative engineer, U. S. Fuel Administration, Bureau of Conservation.

Mr. Meyer became identified with Combustion Engineering Corporation in 1926 and was placed in charge of design and construction of complete fuel burning and steam generating equipment for the Kip's Bay Station of the New York Steam Corporation. This is the largest steam heating plant in the world and it is also believed to be capable of greater steam production per square foot of ground area than any existing power station.

* * *

W. S. Unger, formerly with the blast furnace department of the Duquesne works of the Carnegie Steel Company, Pittsburgh, has been appointed superintendent of the Carrie furnace plant of that company, succeeding J. E. Lose, who recently was advanced to the Homestead works. Mr. Unger was at one time the assistant superintendent of blast furnaces at Clairton, going from there to be assistant superintendent of the Carrie plant in 1924.

* * *

H. B. Carpenter for four years general superintendent for the Colorado Fuel & Iron Company has resigned to become assistant to the general manager of the Republic Iron & Steel Company, of Youngstown, Ohio. Mr. Carpenter has been connected with the Cambria Steel Company, Johnstown, Pa., as assistant superintendent of the coke plants and with the Jones & Laughlin Steel Corporation, Pittsburgh. He went to the Colorado Company in 1916 as superintendent of the coke works.

* * *

William M. Neckerman, of the Youngstown Sheet & Tube Company, has been appointed general manager of the Republic Iron & Steel Company, succeeding J. W. Deetrick, resigned. Mr. Neckerman has been connected with the Sheet and Tube Company, for 21 years and is a leading authority on pipe mill operations.



THE STEEL PLANT ROLL TURNER AND DESIGNER

Nearly Forty Years of Service to the Steel Industry

Mr. W. F. Lewis has completed over 20 years of service as superintendent of the roll shop at the Duquesne Works of the Carnegie Steel Company. His knowledge of roll designing is well founded on extensive experience and education. Prior to his work



W. F. LEWIS

at the Carnegie Steel Company he served for 10 years as draftsman, roll designer, and superintendent of roll shops at the Cambria Steel Company. A period of eight years as assistant chief mechanical engineer with the Mackintosh-Hemphill Company completed a training in all branches of the steel rolling mill industry.

Temperatures for Rolling

Harry Brearley* has pointed out that although the tensile strength of cold steel usually varies between 44,000 and 222,000 lbs. per square inch, the tensile strength of steel heated for rolling may be as low as 2,200 lbs. and rarely exceeds 6,600 lbs. per square inch, and that while the effort required to roll hot steel decreases as its temperature rises, a maximum work-

*Heat Treating and Forging.

ing temperature is fixed for steel of any given composition, by the fact that steel begins to melt at a temperature much below that which is needed to melt it completely. The more carbon a steel contains the hotter it must be in order to be manipulated by a given effort; but, on the other hand the steels higher in carbon begin to melt at lower temperatures than those lower in carbon, that is, where high temperatures are most needed they are least permissible. A rolling mill just powerful enough when taking fixed draughts to roll a wrought iron bloom of given dimensions reheating to 700 deg. C. could not roll a similar bloom of mild steel unless it were reheated to some higher temperature, and as the hardness of the steel increases the reheating temperature would need to be increased also. The minimum rolling temperatures range from 700 deg. C. for a 0.1 carbon steel to 1,100 deg. C. for a 1.2 carbon steel while the danger line ranges from 1,500 deg. C. for a 0.1 carbon steel to 1,150 deg. C. for a 1.2 carbon steel.

An Example of Roll Design for a Three-High Blooming Mill*

(Continued from last issue.)

Second: The most suitable pitches for the rolls are determined. By pitch is meant the distance from center to center of a pair of rolls without clearance, or the distance between any two of the pitch lines. These are based on the size of the mill; the average pitch for the top and bottom sets of passes are equal to its size, and should be such, for reasons already noted, that each roll will be approximately $\frac{1}{4}$ in. less in diameter than the one above it. The pitch is, therefore, determined by trial as follows: In this case the proper figures appear to be—

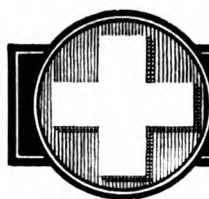
40 $\frac{1}{2}$ in. from center to center of top and middle roll.
43 $\frac{1}{2}$ in. from center to center of bottom and middle roll.
(84 in. $\div$ 2 = 42 in. = the size of the mill.)

From these figures the working diameter of the passes are found as follows:

43 $\frac{1}{2}$ in. pitch of bottom and middle roll.
19 $\frac{1}{2}$ in. height of first pass, (See size of bloom for No. 1 pass.)
2 $\overline{23\frac{3}{4}}$ in. pass diameter of first pass.
11-13/16 in. — 1/16 in. = 11 $\frac{3}{4}$ in. first pass radius of bottom roll, or first pass working diameter = 23 $\frac{1}{2}$ in.
11-13/16 in. + 1/16 in. = 11 $\frac{7}{8}$ in. first pass radius of middle roll, or first pass working diameter = 23 $\frac{3}{4}$ in.
11 $\frac{7}{8}$ in. + 17 in. (size of No. 2 pass) = 28 $\frac{7}{8}$ in.
40 $\frac{1}{2}$ in. (pitch of top and middle roll) — 28 $\frac{7}{8}$ in. = 12 in., first pass radius of the top roll; or first pass working diameter of top roll = 2 in. $\times$ 12 in. = 24.
As this diameter is a little larger ($\frac{1}{4}$ in.) than that for the middle roll, the pitches assigned above are assumed to be the proper ones.

*The Making, Shaping and Treating of Steel. Carnegie Steel Company.

(To be continued)



SAFETY FIRST IN THE STEEL PLANT

General Reports on Steel Mill Safety

The report of the National Safety Council brings out much interesting statistical data. Eighty-two steel plants totalling 107,474 employees show, in 1927, 35 deaths, 219 permanent disabilities and a total of 6,230 accident cases, the frequency rate being 21.13 per cent and the severity rate 1.77 per cent. This is a considerably better showing than that of 1926, and places the steel industry on a very good comparative basis. It is a very creditable result of the earnest efforts of all and of the intensive work of those directly connected with safety campaigns. There can be no doubt but that the showing has been made against great odds in the natural hazards incident to the production operations. It has not just happened, but the credit has been earned by unusual endeavor.

Some Safety Records Attained

The Monongahela Connecting Railroad serving the Pittsburgh plants of the Jones & Laughlin Steel Corporation has completed a period of 5½ months without a lost time accident. The road employs about 500 men and the period covers 605,000 man hours. The Aliquippa Works of the corporation reduced their accident severity to 0.12 per cent and during the month of March to 0.06 per cent. The blast furnace department of this works had no lost time cases in March at the same time setting a world's record at the No. 5 furnace of 1,185 tons in one day, the average daily production of this furnace for the month being 977 tons.

The Indiana Harbor coke plant of the Youngstown Sheet & Tube Company, has completed 365 consecutive days without a single lost time case placing the department in the "one year without accident" club including the blast furnace, Bessemer, bloom, billet and bar, electrical, masons, ore docks and inspection departments.

The Bethlehem Steel Company electrical department has completed a year without a lost time case.

The Edgar Thompson Works of the Carnegie Steel Company reports a year in the heating and rolling department without a lost time accident.

The Commonwealth Steel Company shows unusual records showing long periods in many departments without lost time accidents leading off with the pipefitters with 1,767 days and including the open-hearth with 533 days.

Safety and American Industry

Safety and its allied branches, plant surgery, welfare and the health of the worker have been a blessing to American industry during the last 20 years. Those who started the safety movement in our steel mills and manufacturing establishments planned and builded better than they knew. Safety, as an integral part of American industry, is scarcely 20 years old at the present time, yet, those who have studied its application and progress can declare with absolute certainty that it has brought with it blessings alike to employer and employee. In addition to saving human life and limb, it has been a very vital factor in bringing our industries to their present high state of efficiency, and it has brought a better understanding between employer and employee than has ever been known in the history of the world. The safety director in co-operation with the plant surgeon, the employment manager, and the welfare nurse form a quartet which performs a service not only to the industry that employs them, but also to the entire community. In order to have a safe worker it is also necessary to have one who is healthy and whose home surroundings are conducive to contentment and happiness. It has, therefore, developed that safety, plant surgery, and welfare link themselves up to the workmen's entire life and seek to assist him not only to work safely while at

the plant but so to plan his life that he may realize to the full life's greatest pleasures.

—From Labor & Industry, April, by John A. Oartel,
Chief Safety Engineer, Carnegie Steel Company.



Mr. J. E. Culliney is safety director of the Bethlehem Steel Company at Bethlehem, Pa. He is also a member of the executive committee of the Metals Section of the National Safety Council.

A Correction

In the April issue of BLAST FURNACE AND STEEL PLANT on page 534 "Safety First in the Steel Plant" an error was made giving the location of Mr. H. E. Hensel, Youngstown Sheet & Tube Company, as Youngstown, Ohio, instead of Chicago, Ill. Mr. J. M. Woltz is the company's director of safety at Youngstown.

Steel Man Heads Wheeling Council

Isaac M. Scott, president of the Wheeling Steel Corporation, Wheeling, W. Va., has been elected president of the Wheeling safety council for the year.